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Propagation

A Journal of Science Communication

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Editorial

The current issue of *Propagation* contains eleven papers of contemporary relevance in selected fields contributed by eminent science centre professionals, science communicators, museologists, science historians, scientists and technologists.

The authors of the paper 'Marketing Science Centres', based on their long standing experience, draw our attention to the pros and cons of this challenging task. Their findings, we believe, will immensely help the new entrants to science centre profession. The article 'Scientific Discoveries, Technological Innovations and Modern Warfare' reviews the influence of science and technology on progressive development of accurate, powerful and deadly weapons and their use in three major modern wars. 'Engineering Education in India: past, present and future' presents a detailed analytical survey of technical education imparted through Universities, IITs, Polytechnics between 1900 and 2005. The paper on 'Stone Technology in India' seeks to capture man's intelligent use of stone through ages for utilitarian and non-utilitarian purposes. The story begins with the distant stone age and comes down to contemporary period.

The article 'Social Inclusiveness of Indian Science Centres & Museums ......" establishes through questionnaire surveys, statistical analyses and auditing the fact that the Indian Science Centre/Museum community has proved its relevance in the changing environment of society especially in terms of physical, cognitive, and economic accessibility. 'Science Broadcasting' explores the problems and prospects of science broadcasting in India and suggests strategies for improving the quality of science communication through electronic media. The paper, 'Portrayal and preservation of indigenous methods of Visual Communication' traces the evolution of various methods of visual communications through the ages and argues that Indian museums should utilize such methods for communication.

There are two short but comprehensive and informative articles in this issue, 'The Amazing World of Nanotechnology' and 'Tribology: A Potential Source of Energy Saving in Industry', contributed by experts from the respective fields.

The paper 'Glimpses of cosmic menagerie through S. Chandrasekhar's eyes' provides an exposition to Subrahmanyan Chandrasekhar's seminal contributions in astrophysics - from white dwarf mass limit to black holes and gravitational waves. The article is our homage to the legendary astrophysicist on the occasion of his birth centenary celebrated in 2010. The article 'Sir M. Visvesvaraya – An engineer par excellence' is a 150th birth anniversary tribute to this towering personality of India whose contributions have helped in the social and economic well being of the nation.

We sincerely hope that the variety and richness of the contents of this issue will be of interest to readers.

Jayanta Sthanapati
Chief Editor

Propagation
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CONTENTS

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Marketing Science Centres

Marilyn Hoyt, G. S. Rautela & Michael Savino

Abstract

Science Centres continually seek to increase the size of their audiences—to serve as many of the public as possible. At the same time, it is becoming increasingly necessary to allow those who use science centres to help support the costs of their services. Their fees are part of "earned income" and earned income is key to sustaining the quality of existing exhibits, programs and demonstrations. And it is also key to trying new ideas. The annual cycle of marketing activity and expenditures keeps both of these goals in mind. However, in India the former goal gets priority as science centres are largely funded by the government except in case of Science City, Kolkata which is built and run as a self-sustainability model.

Admissions Marketing: A Different Mindset

When thinking about audience development, science centres often consider marketing as an expense, rather than as an investment. After all, if a science centre offers a quality experience, why should there be a need to spend money on paid advertising, public relations and audience surveys?

The answer is simple: the "Build It and They Will Come" philosophy, so prevalent across the United States and elsewhere, simply does not guarantee success. Time and time again we see examples of science centres failing to achieve and maintain attendance goals.

Rather, when faced with competition from shopping, entertainment and recreational opportunities, ever-changing public interest, and fluctuating economics—science centres must take a different approach. They must be willing to ask the hard questions about the visitor experience—their "product". And they need to ask questions about how they deliver that product.

Fig. 1. Science Playground built on the Indian model: New York Hall of Science.

Fig. 2. Coney Island Wonder Wheel: Dan Wharton.

On any given day, visitors have many choices for an outing

A good place to start is to look at your institution and ask three basic, yet difficult questions about what your science centre does:

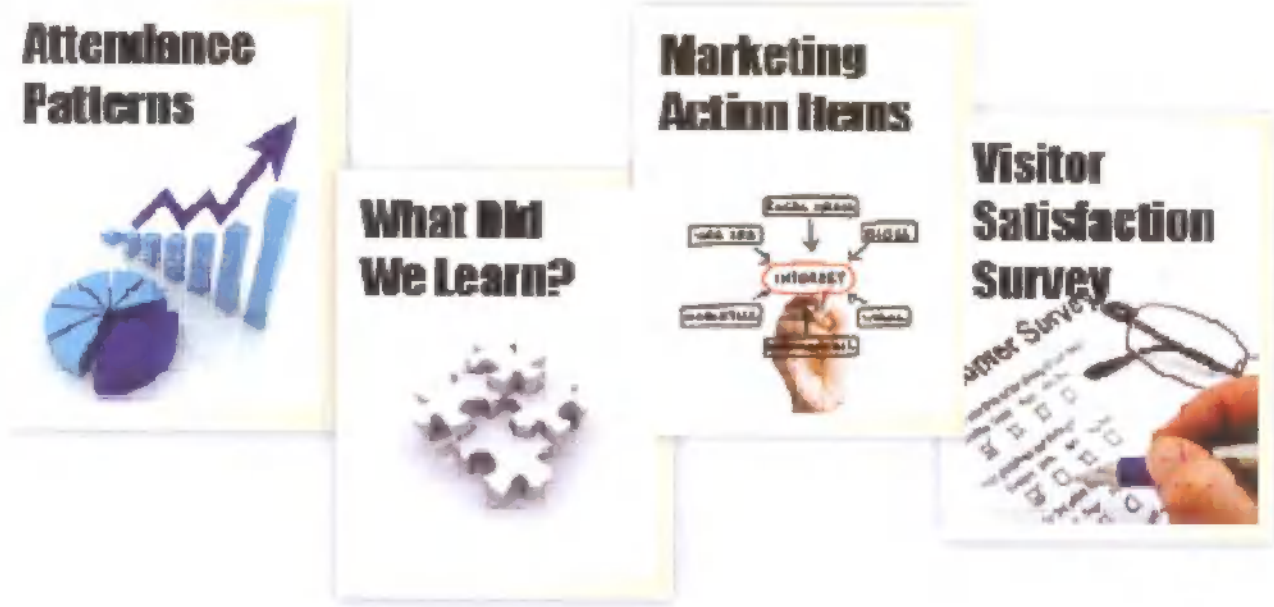
* "So what?"
* "Who cares?"
* "What does it mean to the visitor?"

Asking these questions can be challenging, yet this is an ideal way to get into the mindset of a potential visitor. The public does not arrive at your admissions desk simply because you exist. They have gone through a consumer's decision-making process and have determined that on this particular day, coming to the science centre is their first choice.

Start Every Plan with Research

So who are these consumers and how do you best reach them? In order to maximize resources, all planning should start with research:

* To determine what you already know
* To determine what you learn from others
* What did we learn from attendance?



Whether you're considering creating a new exhibition, bringing in a travelling exhibition, launching new demonstrations, or developing a marketing plan, each effort should begin with research.

Ascertain what's been done, what's worked, who your competitors are, timing, pricing, etc. Think about personal consumer habits.

Research data can be gathered in many ways, both from primary and secondary sources. The Association of Science-Technology Centres commissions annual research surveys which can be purchased. And local tourism and city economic studies, or data from NCSM journals and the annual report can be very useful. This data can include trends in consumer-spending and attendance as well as benchmark comparisons. Also, don't hesitate to talk with colleagues from other cultural institutions in your city—or your science centre colleagues across the country. It is always helpful to understand what is typical about attendance patterns among your peers, and what is different at your particular science centre. Likewise, it is helpful to understand what types of offerings are successful in drawing visitors of different ages and background, and what pricing and seasons seem to be most popular. Learning from others is a good first step.

Your visitors are the primary source of marketing information for your science centre. To understand them, you can conduct brief, targeted surveys. Following these six simple steps can yield valuable results, including must-have action offerings:

1. Brainstorm with co-workers what it is you need to know from your audience that will help you manage your facility, determine your mix of offerings, and price what you offer while you grow attendance.

2. Develop a focused list (no more than 10) questions that will help you learn what it is you need to know.

3. Determine the best way to implement this questionnaire (small groups, visitor exit interviews at your science centre and outside the centre, mailer, web site, etc.).

4. Collect the responses. You may need to provide an incentive for respondents -- free tickets to special shows, a science centre pen or key chain -- in order to increase participation.

5. Compile the data.

6. Now get back with that brainstorming group and determine what you've learned and what you are going to do with your findings.

SAMPLE VISITOR EXIT SURVEY

1) Is this your first visit?

(follow up question if first: "How did you hear about the science center?")
(follow up question if have come before: "How many times do you come in a year?")

2) Can you tell me how many adults and children came with you today?

(follow up question if children: "What are the ages of the children?")

3) What were your interests in coming to the science center? (check all that apply)

Interest in science/technology	☐	Bring children	☐
Entertainment	☐	Bring guests	☐
Educational	☐	Recommended by friends	☐
Holiday/sightseeing	☐		

4) What were some of your favorites today (As needed, prompt with names of exhibits, workshops, demonstrations, IMAX shows)

5) Did you buy Special show tickets (list purchase opportunities)

Did you buy food or snacks?

Did you buy souvenirs at the gift counter?

6) Did you talk with or ask help of any staff while you were here?

(follow up question to ascertain what kind of staff – uniformed?, in exhibits etc.)
(follow up question: Were staff helpful? Unhelpful? In what way?)

7) Did you experience any inconveniences in your visit today?

8) What parts of your visit today did you like best?

9) We want to understand where our visitors come from? Can you tell us what neighbourhood or village you live in?

10) What language(s) do you speak at home?

This process is only valuable if you act on what the data tells you. Even if you cannot fully respond to visitor input, you can usually begin with a response. (For instance, if exhibit labels are too detailed or the print is too small, you may incorporate this feedback as you develop new exhibitions. You may or may not be able to fund the redesign of existing labels. Likewise, if visitors complain about unclean restrooms and a part of the problem is that the fixtures themselves need to be replaced, you can nonetheless keep floors and existing fixtures very clean at all times.)

The Core Visitor

Key to admission marketing is understanding core audience. Simply defined, the science centre's core audience is the specific population who attend most often. For example: Many science centres in the world have two core audiences:

* Primary and secondary students coming in school groups.

* Families with pre-teenage children.

The science centre's exhibitions, events and programs are geared toward these people.

To define core visitors, one needs to determine specific demographic characteristics, including age, gender, ethnicity, education, household income, and marital and parental status. This data can be obtained by conducting a survey using the five-step approach previously discussed. For example, if a science centre wants to identify core-audience characteristics:

* A visitor demographic survey can be developed.

* This survey might be implemented at the admission areas by staff or student interns.

* The survey needs to be administered over a period of time. For instance, think about surveying twice a week for six weeks during the period that school groups come most frequently, and on six weekends during the busiest family visitation season.

* Compile the survey results.

* Share results with staff for analysis and feedback.

* Think together and then act on understanding who the decision maker is (the person who brings the visitors), what they are looking for, how often they visit and what represents a "successful" visit. Knowing all these will influence what you say on your web-site and in your advertising, as well as how you design exhibitions, programs and demonstrations.

Helpful tip:

Repeat as many survey questions as possible in subsequent years to keep the questions consistent. This gives you the best chance of assembling parallel data and trends to measure improvement and guide your planning.

Why is it important to have a clear picture of core audience? Simple: this is the target market for your audience development efforts. For overall growth in the numbers you serve, it is easiest and most cost effective to grow more core audience. If your science centre's core audience is a family of two adults with four children—2 pre-schoolers, 1 in elementary and 1 in secondary school—it will be easier to locate, target and grow this audience than to locate, target and develop an audience of two adults without children in the household. If your decision maker is commonly a 30-year-old father or a 23-year-old mother, then you can advertise in print and electronic media which targets them.

Fig. 4.

Plan Annually, Adjust Quarterly

Plans are designed to change, that's true. But when planning your admissions marketing, it's important to take the approach that what you are planning today you will commit to for 12 months. This often means that your marketing plan—including the costs of surveys and advertising, graphics, your web-site, and public relations activities—must be assembled about 4 months before the beginning of your fiscal year so that next year's budget includes your planned expenses.

Plan first and then implement. Avoid the urge to change direction when small bumps appear. Otherwise, you'll end up stuck in a reactionary cycle that's counter productive to your goals. After all, if the plan was well developed, you will need the entire year in order to reach your goals. That's not to say that you shouldn't adjust to the economic climate, to sweeping changes to reduce public travel (like last year's chikungunya outbreak that stifled so many outings in Delhi) or to changing circumstances at your science centre. Plan your 12-month marketing campaign, schedule your media buys and public relation releases, design and produce your pieces and release them on schedule. If your calendar includes running a promotion during a particular period, don't back away from that strategy simply because the previous months may have been tough. Stay the course.

Fig. 5. You never plan to fail but fail to plan!

Helpful tip:

How much should we budget? 5% of a science centre operating budget is a common benchmark for designing, producing, and buying space for advertising. However, science centres that depend upon earned income to support more than 50% of their operating costs often spend more. And other science centres spend less. The key is to start with the assumption that buying advertising to publicize the most popular offerings at the most popular seasons of the year should help increase your total visitation. Remember to think about marketing as an investment in audience growth, not an administrative expense.

Scenario in India-Mind-Set

Science Centres in India are largely public funded institutions, therefore, who comes or does not come, hardly matters. Quality of exhibit not the visitor experience or satisfaction, is still regarded as the key parameter of success.

'Build it and they will come' is still the perception in most of the science centres. The builder's satisfaction or curatorial brilliance matters not what visitors would take it as or experience or benefit from, is not the concern of the developer. Market driven approach or practicing marketing as a tool, is yet to be accepted as a key function of science centres. Science Centres under National Council of Science Museums network, however, have in principle, incorporated marketing in their mission. Audience and revenue targets are set in successive annual plans. These targets are monitored and extra efforts are put to achieve them. Visitor feedback, responses or audience/market research is negligible with exception in Science Centres under NCSM (there are some centres outside NCSM network) who gather audience data at regular intervals and take remedial measures.

To understand audience one needs authentic research data. But in Indian Science Centres no marketing or audience research units function. It is practiced to some extent through education staff.

The visitor exit survey questionnaire is often too long. This results in casual responses from visitor who do not show enough interest. No incentives for filling the survey form are offered. We need to act on visitor responses. Some of the visitor complaints or suggestions are simple to implement.

What's working in Science Centres in India?

Even though *'marketing'* as a tool to enhance audience base and revenue in Indian Science Centres is not a key function; Science Centres under the National Council of Science Museums network implemented several uniform marketing activities based on success in some Science Centre or localized schemes to market the Centres. In fact, now annual target for audience numbers and revenue generation are set 3 months prior to beginning of a fiscal year (A fiscal year starts on April 1 and ends on March 31). Quarterly reviews by central administration and monthly reviews by individual centres help to take corrective measures or augment efforts to achieve targets. Audience surveys are regular and actions to meet audience expectations as learnt from surveys are taken periodically. Efforts that have brought a fair degree of success include:

* **Inclusive, responsive, reflective approach.**
* **Segment Marketing.**
* **Creating strong brand 'science education resource centres'.**
* **Focusing on repeat visitors to create *'Word of Mouth'*.**
* **Creating new experiences and periodic content upgradation.**
* **Use of digital technology.**

Under the inclusive approach, special events, attractive revenue options including economical package options, inexpensive tickets including free entry for under privileged and poor sections of society, were implemented across all science centers. Activities for various segments; homemakers, differently abled, school dropouts or unschooled, senior citizens, teachers, students, tourists were introduced. This approach brought in many first time visitors that had multiplying effect on repeat visitors.

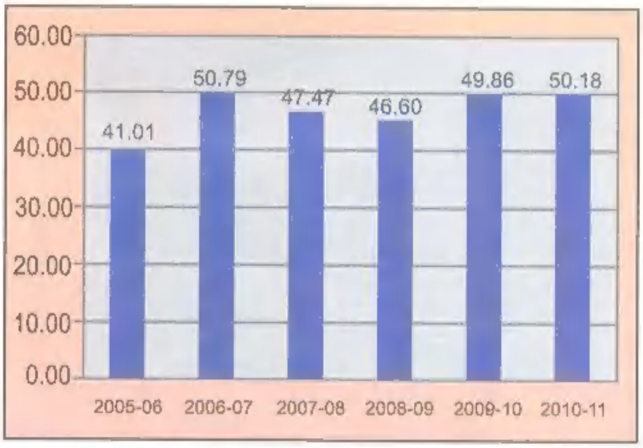


Fig. 6. Repeat visitors (%) to Science City.

Fig. 7. Auto drivers day at Science Centre in Kerala.

Fig. 8. Technology access programme for senior citizens.

Once exposed to the unique and satisfying experience of science centres, the same audience becomes publicity generator or key influencer. For example an 'Auto Drivers Day'- a free visit for the families at a Science Centre in Kerala or 'Taxi Drivers Day' at Science City, Kolkata, helped to develop canvassers in auto drivers for science centres.

Under segment marketing, the approach was to reach out to those who either did not visit the Science Centre or were unaware of such facility in the city or town.

Fig. 9. Solar eclipse-watching for village women.

Fig. 10. Reaching out to public - sky watch at sea beach.

Methods such as distributing leaflets to household through newspaper vendors, public at sea beaches, busy market places, parks, traffic junctions, housing complexes, railway stations helped to publicize the centres. However, special events and activities for various segments had greater impact in creating 'word-of-mouth' publicity.

Exit surveys, surveys at public places to assess branding, awareness, opinion, placing in public priority etc. brought in new set of data that provided new insights and helped to design new programmes, exhibit themes, pricing policy etc. One startling revelation was made by such survey at Science City, Kolkata was its image as an expensive and entertainment venue. Subsequently advertisements 'See Science City at Rs.20/-' and focusing on educational role of Science City paid dividend and resulted in almost 25 per cent increase in footfall and substantial increase in revenue generation. Similarly, the survey in Nehru Science Centre, Mumbai, brought out need for opening the Science Centre one hour earlier for schools. A small intervention, changing the opening hours from 11:30 am to 10:30 am increased the student visitors by over one hundred thousand.

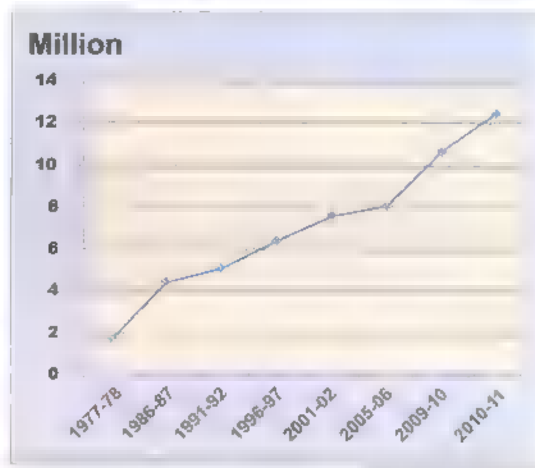


Fig. 11. Visitors to science centres under NCSM (combined)

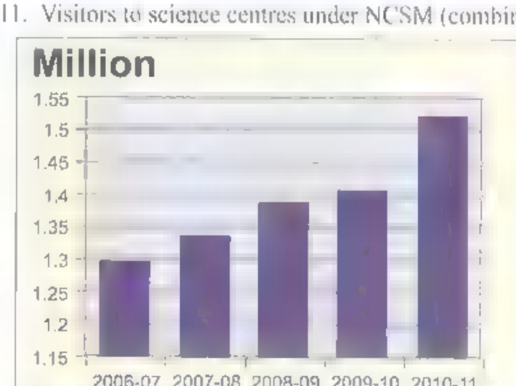


Fig. 12. Visitors to Science City, Kolkata.

The Science Centres in India also regularly upgrade their content and experiences i.e., exhibits on new themes, new science shows and demonstrations, and new engaging activities. This has resulted in increase of footfall, specially repeat visitors and consequential revenue generation.

Fig. 13. Modernization of Exhibition Galleries.

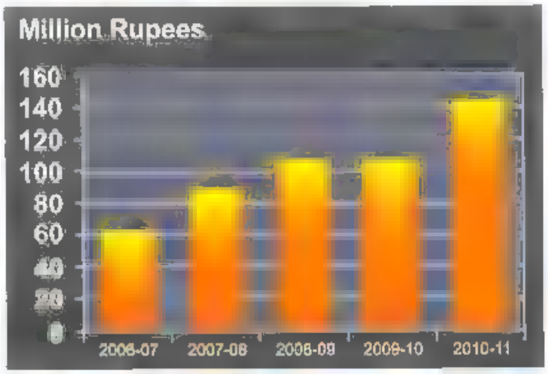


Fig. 14. Revenue growth from public in NCSM centres.

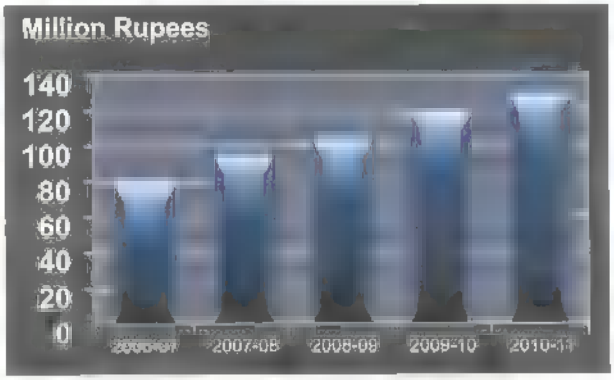


Fig. 15. Revenue generation at Science City.

Marketing of Science Centres needs a professional and business like approach as they deal with variety of audiences having divergent economic, social, psychological and educational backgrounds. Marketing also needs to be accepted as a key function of Science Centres irrespective of their financial operating model if they have to remain relevant and succeed in their goals.

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Scientific Discoveries, Technological Innovations and Modern Warfare

Jayanta Sthanapati and *Kunal Chattopadhyay*

Abstract

The article reviews the influence of scientific discoveries and technological innovations, since early modern period, in progressive development of accurate, powerful and deadly weapons and their use in three major modern wars, namely, the American Civil War, the First World War, and the Second World War, fought between 1861 and 1945, which revolutionized the character of modern warfare.

1. Introduction

War is a state of organised and coordinated armed conflict carried out between states or parties within a nation, between two nations, or between groups of nations, which invariably causes societal disruption and high human mortality. From the earliest conclusive archaeological evidence it transpires that the earliest human attack on a human settlement took place between 12,000 and 14,000 years ago near the present day town of Jebel Shaba in Sudan. By 2000 BC, war originated independently in different parts of the world.

While wars are guided by strategy, battles take place on a level of execution of such strategic planning. Throughout recorded history of mankind, since ancient to recent times, military engagements have always had significant impact on world history. In 1851, eminent English historian Edward Shepherd Creasy identified 15 decisive battles of the world fought between 490 BC and AD 1851. Description of 100 decisive battles from the Egyptian battle at Megiddo in the 15th century to the military action in Persian Gulf War in 1990-1991, portraying the impact of such battles on the shaping of world history, has been given by Paul K. Davis in 1999.

Historians in general agree that the Military Revolution in Europe took place due to radical change in military strategy and tactics during the period between late medieval era and the early modern period. Michael Roberts was first to propose a concept of military revolution in 1956. He believed that such a revolution happened around 1560-1660, due to advancement of fire weapons. According to Geoffrey Parker, military revolution spanned over a period from 1500 to 1800, when Europeans achieved supremacy over rest of the world. Jeremy Black gave an exhaustive account as to how war has been waged over the past five-and-a-half centuries in the European and non-European worlds. He pointed out that while European warfare revolutionised during the 19th century, the Ottomans during 13th to 16th century, the Mughals in the 16th century, and the Manchus in the 17th century were formidable in their own right. Kausik Roy has described how 12 great battles have changed the course of Indian history from 326 BC to AD 1999.

Scientific discoveries and technological developments during the periods of European Scientific Revolution, and Industrial Revolutions in Europe and subsequently in America, had greatly influenced development of military weapons used in modern warfare from mid-nineteenth century to the end of the twentieth century. Ernest Volkman stated that military generals have always turned to science in their quest for ever-more-terrible weapons and cited examples of non-military scientific inventions that were useful for military purposes. The inter-relationship of science and warfare for centuries has been laid down by Antonie J. Bousquet. In this article we present the impact of science and technology on warfare in three modern wars, namely, the American Civil War, the First World War, and the Second World War.

2. Major revolutions influencing warfare

The world is believed to have passed through four major revolutions that directly or indirectly brought out such technologies which enabled mankind to develop more and more deadly weapons since 1300. In the present section we discuss three of them which have had direct relation to the modern wars between 1861 and 1945.

2.1 The Gunpowder Revolution

Gunpowder, the first man-made explosive, was invented in the 9th century in China. The correct prescription for making gunpowder with saltpeter, sulphur and carbon appeared in the early 11th century Chinese literature. The Arabs and the Indians acquired the knowledge of gunpowder during the middle of the 13th century. It was thereafter introduced in Europe, which brought in revolution in weapons manufacture as well as tactics on the battle fields. Italy was the first to develop gunpowder weapons in 1326. Such weapons were introduced in France in 1338, in Germany in 1340, and in England in 1944. Warfare in the early modern period was dominated by widespread development and use of gunpowder weapons. Sections 5.1 and 6.1 give some details of gunpowder weapons used in modern warfare.

2.2 The Scientific Revolution

The scientific revolution is the name given by historians of science to the period of European history between 1543 and 1700, when conceptual, methodological and institutional foundations of modern science were first established.

Nicholaus Copernicus (1473-1543), a polish astronomer and mathematician, in his book *De revolutionibus orbium coelestium* (On the revolutions of the celestial spheres), published in 1543, formulated a comprehensive heliocentric cosmology, which displaced the then existing concept of geocentric cosmology propounded by the Egyptian geographer and astronomer Claudius Ptolemy (c 90-168). Historians of science are of the opinion that Scientific Revolution began in Europe with the publication of the book of Copernicus.

During the period of the Scientific Revolution, concepts in physics, astronomy, human anatomy and biology transformed the beliefs that had prevailed in ancient Greece and continued through the Middle Ages in Europe. During this period, Tycho Brahe, Johnnes Kepler, Galileo Galilei and Isaac Newton made significant contributions to scientifically unravel the mysteries of the universe. Tycho Brahe (1564-1601), a Danish astronomical and planetary observer, proposed a model of the universe that could be considered as both geocentric and heliocentric, where the Sun moved round the Earth, but all other heavenly bodies moved around the Sun. Johannes Kepler (1571-1630), a German mathematician and astronomer, based on astronomical data collected by his mentor Tycho Brahe, created three laws of planetary motion. Italian physicist, mathematician, astronomer and philosopher Galileo Galilei (1564-1642) made further advancement to the theory of the universe. Through his telescope, Galileo observed that the Moon had mountains, and the planet Jupiter had four satellites. He formulated the idea of gravity that could accelerate the motion of a falling body.

Isaac Newton (1642-1727), an English physicist, astronomer and mathematician, described universal gravitation and three laws of motion which governed the scientific view of the physical universe in his book *Philosophiae Naturalis Principia Mathematica* published in 1867.

Andreas Vesalius (1514-1564), an anatomist and physician in the Habsburg Netherlands, published one of the most influential books on human anatomy *De humani corporis fabrica* (On the fabric of the human body) in 1543. The book rectified some of the misconceptions about human anatomy laid down by Claudius Galenus (Galen of Pergamon) (129-199/217), a Roman physician, surgeon and philosopher during the second century AD. William Harvey (1578-1657), an English physician, was the first person to describe that the heart pumped blood from the atria into the ventricles and then into the rest of the circulatory system. His book *Anatomical Exercise on the Motion of the Heart and Blood in Animals* (1628) too overturned some of the concepts of Galen.

Establishment of a scientific society and an academy in Europe gave impetus to the Scientific Revolution. They provided ample opportunities to the philosophers of the period to discuss and publish their observations, hypotheses and findings with like minded intellectuals. The Royal Society, a private institution and the oldest learned society for science in existence, was founded in London in 1660. The Academy of Sciences, a government institution, was established in Paris in 1666.

2.3 The Industrial Revolutions

Industrial revolutions had a major impact on all aspects of human society and culture. It refers to a period from the mid-18th century to the early 20th century when unprecedented advancements in agriculture, mining, manufacturing, transportation and technology had occurred. Modern historians call the period between the 1760s and the 1840s as the 'First Industrial Revolution' which is characterised by development of textile manufacture, iron making, and steam power, led by Britain. They call the period from the 1850s to the 1910s as the 'Second Industrial Revolution' when steel, electrical technologies, automobiles, and aircrafts were introduced. These are presented in section 4 of this article. There are numerous applications of the industrial developments in warfare which happened between 1792 and 1918, a few of them are detailed in sections 5 and 6.

3. Science in the 18th and 19th centuries

3.1 Physics

Between the 18th and 19th centuries, physics advanced to a great extent, both in terms of development of theories and experimentation. In 1704 Isaac Newton's book *Opticks: A Treatise of the Reflections, Refractions, Inflexion and Colours of Light* was published. Daniel Bernoulli (1700-1782), a Dutch-Swiss mathematician, did pioneering work in fluid mechanics, probability, and statistics. His book *Hydrodynamique* was published in 1738. Benjamin Thomson (1753-1814), an Anglo-American physicist published his paper 'An Experimental Enquiry Concerning the Source of the Heat which is Excited by Friction' (1798) in *Philosophical Transactions* of the Royal Society and initiated the revolution in thermodynamics that would take place in the 19th Century.

Nature of light was studied extensively during the 19th century. William Herschel detected infrared light (1800); Johann Wilhelm Ritter (1776-1810), a German physicist and chemist discovered ultraviolet light (1801); and German optician Joseph Von Fraunhofer (1787-1826) discovered dark absorption lines (1814) in Sun's spectrum. English physicist Thomas Young (1773-1829) in 1802 developed the wave theory of light. French physicist Augustin-Jean Fresnel (1788-1827) studied the behaviour of light both theoretically and experimentally. He demonstrated the wave nature of light in 1816. Young and Fresnel demonstrated in 1817 that light waves vibrate transversely. Albert Abraham Michelson (1852-1931), an American physicist, measured the speed of light in 1879. James Clerk Maxwell (1831-1879), a Scottish physicist and mathematician formulated classical electromagnetic theory of light in 1861. German physicist Heinrich Rudolf Hertz (1857-1894) clarified and expanded the theory and in 1888 generated and detected radio waves. German physicist Wilhelm Conard Röntgen (1845-1923) produced and detected a type of electromagnetic radiation, known as X-rays.

Great advancement in the field of electricity and electromagnetism happened in the 19th Century. Allessandro Volta (1745-1827), an Italian physicist in 1800 invented electric battery, a continuous source of current electricity. Danish physicist Hans Christian Oersted (1777-1851) discovered in 1820 that electric currents create magnetic fields, which established the theory of electromagnetism. Michael Faraday (1791-1867), an English physicist and chemist built an electric motor in 1821 and demonstrated that electrical forces can produce motion. Michael Faraday in England and Joseph Henry (1797-1879) a physicist in America independently discovered the phenomenon of electromagnetic induction in 1831. Faraday in 1832 announced his Laws of Electrolysis.

3.2 Astronomy

Astronomers of the 18th century made precise measurements of position and classification of heavenly bodies. During the 19th century they applied the existing knowledge in mathematics, physics, chemistry and geology to understand the make-up of these bodies. English astronomer, mathematician and physicist Edmond Halley (1656-1742), published his book *Synopsis Astronomia Cometicae* in 1705, wherein he stated that the comet seen in 1456, 1531, 1607 and 1682 related to the same comet and predicted that it would be seen again in 1758. Thomas Wright (1711-1786), an English astronomer and mathematician described the shape of the Milky Way in 1750. Another English astronomer James Bradley (1693-1762) made two fundamental discoveries in astronomy, the aberration of light and nutation of Earth's axis. He also compiled a catalogue of 60,000 stars. A catalogue of more than 100 nebulae was compiled in 1781 by French astronomer Charles Messier (1730-1817). German-born British astronomer Frederick William Herschel (1738-1822) built a 40-ft. long reflecting telescope in 1800. He discovered the planet Uranus and its two moons in 1781. It was the first planet to be discovered since antiquity which sparked a new interest to search for new planets in the solar system. A series of minor planets, or asteroids: Ceres, Pallas, Juno, Vesta, Astraea and Hebe were discovered between 1801 and 1847, while looking for a planet between Mars and Jupiter. Further, based on mathematical prediction, Johann Gottfried Galle (1812-1910), of the Berlin Observatory and Heinrich Louis d'Arrest (1822–1875), a student at the University of Berlin, discovered the planet Neptune in 1846.

In 1859, Robert Wilhelm Bunsen (1811–1899) and Gustav Robert Kirchhoff (1824–1887) discovered that the spectrum of sunlight produced by a prism could be compared with spectra produced by chemicals burned in the laboratory, and by applying this method the elements present in the Sun could be found out. Venus passed across the face of the Sun in 1761 and 1769, again in 1874 and 1882.

3.3 Chemistry

Significant advancement in the field of fundamentals of chemistry was made possible due to extensive experimentation by the learned European chemists of the 18th and 19th century. The nature of air was discovered during the second half of the 18th century. Daniel Rutherford (1749-1819), a Scottish physician, chemist and botanist isolated nitrogen in 1772. Two years later Joseph Priestly (1733-1804) an English natural philosopher isolated oxygen. Joseph Black (1728-1799), a Scottish physician discovered carbon dioxide in 1776. British physicist and chemist Henry Cavendish (1731-1810) discovered hydrogen in 1766 and also demonstrated in 1783 that water was made of oxygen and hydrogen. Antoine Lavoisier (1743-1794), a French nobleman, discovered that although matter may change its form and shape, its mass always remains the same. In 1789 he listed 23 of the elements we find today in the periodic table. Joseph Louis Proust (1754-1826), a French chemist propounded the law of definite proportions, which states that a chemical compound always contains exactly the same proportions of elements by mass.

John Dalton (1766-1844), an English chemist, physicist and meteorologist did pioneering work in the development of modern atomic theory in the early 19th

century. Thereafter, Amedeo Avogadro (1776-1856), an Italian savant, propounded the molecular theory. In 1815, William Prout (1785-1850), an English chemist, suggested that hydrogen was the fundamental atom and all other atoms were built up from different numbers of hydrogen atoms. Swedish chemist Jons Jacob Berzelius (1779-1848) worked out the chemical formula notation and in 1818 published his table of atomic weights. Russian chemist Dmitri Ivanovich Mendeleev (1834-1907), created the first version of 'periodic table of elements'.

William Ramsey (1852-1916) a Scottish chemist in 1895 discovered the element helium on Earth. He also discovered other noble gases, namely, neon, argon, krypton and xenon. British physicist Joseph John Thomson (1856-1940) discovered the electron in 1897. French physicist Pierre Curie (1859-1906) was a pioneer in crystallography, magnetism, piezoelectricity and radioactivity. Marie Sklodowska-Curie (1867-1934), a Polish-French physicist-chemist, along with his husband Pierre Curie isolated radium and plutonium in 1898.

3.4 Life sciences

Biological sciences, such as botany and zoology became increasingly professional scientific disciplines over the 18th and 19th centuries. Carolus Linnaeus (1707-1778), a Swedish botanist, zoologist and physician, laid the foundation of modem scheme of naming species of living things. His most important publications were *Systema Naturae* (1735), *Philosophia Botanica* (1751), and *Species Plantrum* (1753). English biologist Edward Anthony Jenner (1749-1823) in 1796 used vaccination against smallpox and in turn saved lives of smallpox victims all over the World.

During 1838-1839, three Germans, Matthias Jakob Schleiden (1804-1881), Theodor Schwann (1810-1882), and Rudolf Virchow (1821-1902) founded the cell theory which states that cells are the basic units of structure in every living things, both plants and animals. Louis Pasteur (1822-1895), a French chemist and microbiologist, proposed the germ theory of disease. He developed "pasteurisation" a process of heating a liquid (especially milk) sufficiently to kill bacteria without changing its flavour, composition and nutrition. English naturalist Charles Robert Darwin (1809-1882) published his book *On the origin of Species* in 1859, wherein he described his theory with evidence in support of evolution of life by natural selection.

3.5 Science Academies

New scientific societies and academies were founded in Europe and America during the 18th and 19th Centuries. They were, the Prussian Academy of Sciences (1700) in Berlin; the St. Petersburg Academy (1725), which is known as Russian Academy of Sciences since 1999; the Royal Danish Academy of Sciences (1742) in Copenhagen; the American Philosophical Society (1743) in Philadelphia; and the Royal Society of Edinburgh (1783). The Royal Astronomical Society was founded in 1820 in London. The British Association for the Advancement of Science was founded in York in 1831 with the primary object of promoting science. In America, the Smithsonian Institution was established for the "increase and diffusion of knowledge" in Washington, DC in 1846. The American Association for the Advancement of Science was founded in 1848 in Pennsylvania. In 1863, the US National Academy of Sciences was established in Washington, D.C. The British Astronomical Association, the senior national association of amateur astronomers in the UK, was founded in London in 1890.

4. Technology in the 18th and 19th Centuries

4.1 Weaving machines

In 1733 English inventor John Kay (1704-1779) patented a wheeled flying shuttle for the hand loom which accelerated weaving and thus was a key factor in the Industrial Revolution. James Hargreaves (1720-1778), an English weaver, invented a multi-spool spinning frame known as 'spinning jenny' in 1764. Another Englishman, Richard Arkwright (1732-1792) also patented a spinning frame in 1768. English inventor Samuel Crompton (1753-1827) in 1779 invented the spinning mule, a machine which spun yarn suitable for use in the manufacture of muslin. In 1785 Edmund Cart Wright (1743-1823), an Englishman, invented the mechanised power loom. In 1790, Eli Whitney (1765-1825), an American, patented the cotton gin, a machine that quickly and easily separates cotton fibre from the seed. Joseph M. Jacquard (1752-1834), a Frenchman, in 1800 invented the mechanical programmable loom.

4.2 Steam road vehicles

A French inventor Nicolas-Joseph Cugnot (1725-1804) built the first steam-propelled three-wheeled vehicle in 1769. William Murdoch (1754-1839), a Scottish engineer, developed Britain's first steam road locomotive in 1784. Oliver Evans (1755-1819), an American inventor, in 1805 built the first amphibious vehicle, a steam-powered vehicle able to move on road as well as in water. Josef Bozek (1782-1835), Czech engineer and inventor built a steam-car in 1815. English inventor Walter Hancock (1799-1852) built a number of steam-powered three-wheeled road vehicles between 1824 and 1836.

4.3 Steam locomotives

Thomas Newcomen (1664-1729), an English ironmonger and Baptist lay preacher, combined the ideas of basic steam engines of English inventor Thomas Savery (1650-1715) and French inventor Denis Papin (1647-1712), to create the first practical steam engine for pumping water in 1712. James Watt (1736-1819), a Scottish inventor, in 1765 redesigned the steam engine making it more efficient than Newcomen's engine and capable of powering a wheel, thus allowing a greater number of applications such as powering a loom in textile factory, powering paper mills, draining mines, and running a steam locomotive.

British inventor and mining engineer Richard Trevithick (1771-1833) built the first full-scale railway steam locomotive in 1804. *Locomotion* built in 1825 by British civil and mechanical engineer George Stephenson (1781-1848) was the first public steam locomotive in the world, which moved through a distance of 12 miles (about 19.5 km) between Stockton and Darlington. The most advanced steam locomotive, *Rocket* was built in Newcastle upon Tyne in 1829 by Robert Stephenson and Company. By 1830, railway lines laid in England grew to 98 miles (about 158 km). Use of railway was primarily made for transportation of men and materials essential for industrialisation.

Belgium, after breaking with the Netherlands in 1830, gave importance to adopting rail transport for stimulating industrial revolution in the new country. The first Belgian steam-powered railway was operated between Mechelen and Brussels (about 24 km) in 1835. By 1843 Belgium had a railway network, constructed by the Belgian State Railways that connected the major cities, ports and mining areas, and also linked to the neighboring countries.

The first German steam-hauled locomotive *Eagle*, which ran between Nurberg and Furth in 1835, was built by Robert Stephenson and Company in Newcastle, England. By 1840s, major cities of Germany were connected by rails. The first Italian railway line covering a distance of 4.5 miles (about 7 km) between Napoli and Portici was opened in 1839. The first railway in the Netherlands operated between Amsterdam and Haarlem in 1839.

Ireland's first railway opened between Dublin and Kingstown, a distance of 6 miles (about 9.5 km), in 1834. In Poland, Warsaw and Pruszków, at a distance of 9 miles (about 14.5 km), were connected by rail in 1844. First railway in Hungary connected Pest and Vác – a distance of 26 miles (about 42 km) – in 1846.

The first Austrian railway line connected a distance of 15 miles (about 24 km) between Vienna with Wagram in 1837. The first railway in Switzerland was a 10-mile-long (about 16 km) line connecting Zürich with Baden in 1847.

The first steam-powered Canadian railway was operated outside Montreal in 1836. The first passenger train in British India was inaugurated between Bori Bunder in Bombay and Thane, covering a distance of 21 miles (about 34 km).

John Stevens, an American inventor, designed and built a steam locomotive that hauled several passenger cars in Hoboken, New Jersey, USA in 1825. The first public carrier railway was operated in the Baltimore and Ohio railroad. A British made steam locomotive *John Bull* was operated in 1831 in New Jersey, USA. In 1831, a railroad between Boston and Providence was opened.

4.4 Steamboats

Steamboats or steamships were used extensively for transportation of men and material from one place to another, before invention of trains, automobiles and air planes. James Watt (1736-1819) a Scottish inventor developed an engine run by steam in 1769. Five years later, Claude de Jouffroy (1751-1832), a French inventor, built *Palimpede*, the first working steamboat with rotating paddles. In 1802, a British Baron, Thomas Dundas (1741-1820) commissioned *Charlotte Dundas*, the first practical steamboat. Rober Fulton (1765-1815), an American engineer, built *Clermont*, the first commercially successful steamboat, in 1807. By 1900, there were about 30 steamboats operating in the world, which came down to less than 10 by 1930.

4.5 Iron and steel

Iron and steel were of great demand during this period for production of machines and weapons. In 1709, Abraham Darby (1677-1717) an Englishman, invented coke smelting, replacing use of charcoal, to melt iron ore during refining the metal. English ironmaster Henry Cort (1741-1800) developed a paddling process for refining iron from pig iron to wrought iron in 1783. An inexpensive industrial process for mass-production of steel from molten pig iron was invented by Henry Bessemer (1813-1898) in 1855. Two years later, an American inventor William Kelly (1811-1888) was granted a patent for independently developing a process of steel making.

4.6 The automobile

French inventor Francois de Rivaz (1752-1828) developed first internal combustion engine powered by a mixture of oxygen and hydrogen in 1807. Siegfried

Marcus (1831-1898), a German-born Austrian inventor built the first automobile in which internal combustion engine was fuelled by gasoline. However, Karl Benz (1844-1929), a German engineer, was the first person to design and develop a practical gasoline-powered automobile in 1885. He was granted patent for automobile in 1888 and production of the vehicle started immediately thereafter. During the remaining years of the 19th century, automobiles were developed by Gottlieb Daimler (1834-1900) and Wilhelm Maybach (1846-1929) in Germany; by Frederich William Lanchester (1868-1946) in 1895 in Britain; and also by John William Lamb art (1860-1952) and Henry Nadig (1808-1860) in USA in 1891.

4.7 Submarine

The first submarine torpedo boat *Turtle* was built in 1776 by David Bushnell (1742-1824), an American inventor. An attempt was made by the crew of 'Turtle' in 1776 during American Revolutionary War to affix explosive to the underside of British Warship 'HMS Eagle' in New York Harbour, but was unsuccessful. Robert Fulton (1765-1815), an American inventor, then living in the French First Republic, designed and built the first practical submarine, the 'Nautilus' in 1801.

4.8 Electrical telegraph

Italian physicist Alessandro Volta (1745-1827) invented the voltaic pile, an early electric battery. Danish physicist Hans Christian Oersted (1777-1851) in 1820 experimentally discovered that electric current creates magnetic field. Influenced by Oersted's discovery, Andre-Marie Ampere (1775-1836), a French physicist performed a series of experiments in 1820 to elucidate the exact nature of the relationship between electric current-flow and magnetism. These experiments led him to formulate laws of electromagnetism. British physicist and chemist Michael Faraday (1791-1867) in 1831 discovered electromagnetic induction: the induction or generation of electricity in a wire by means of electromagnetic effect of a current in another wire. He also developed the first dynamo in the form of a copper disk rotated between the poles of a permanent magnet. American scientist Joseph Henry (1779-1878) had also discovered the phenomenon of electromagnetic induction in 1831, but Faraday was first to publish his results. Henry later developed electromagnetic relay, an electromechanical switch.

Samuel F.B. Morse (1791-1872), an American painter, travelled to Europe in 1832 and heard of Faraday's work on electromagnetic induction. He also learnt about Henry's electromagnetic relay. Several attempts were made by Europeans in the following years to develop telegraph. In 1835, Morse built the first American single-wire telegraph. He also developed the Morse Code, a method of transmitting textual information as a series of on-off tones. Morse patented his telegraph machine in 1837 and was able to send the first telegraphic massage "What hath God wrought" from Washington, D.C. to Baltimore in 1843, at an approximate rate of 10 words per minute.

4.9 Electrical technology

Michael Faraday's work of 1831 on electromagnetic induction in England led to a chain of inventions in electrical technology in the 19th century, such as electric motor by English physicist William Sturgeon (1783-1850) in 1832; dynamo by French instrument maker Hippolyte Pixii (1808-1835) in 1832; power transformer by Englishman Lucien Gaulard (1850-1888) in 1881; single-needle telegraph by Pavel Schilling (1780-1837) in Russia in 1832; and telephone by Alexander Graham Bell (1847-1922) in 1876 in America. Thomas Alva Edison (1847-1931) operated the first commercial electricity generating station in America in 1882, which provided direct current (DC) to its customers. Another American, Nikola Tesla (1856-1943) invented alternating current (AC) generator in 1888, and soon thereafter commercial AC supply began in the US.

5. American Civil War

The American Civil War, fought during 1861-1865, was a conflict between the Northern states (the Union) and the Southern states (the Confederacy). It was the bloodiest war in American history that claimed lives of some 6.2 million soldiers in course of thirteen battles. Sectional strife between northern and southern states, on issues like states' rights, territorial disputes and slavery, emerged in the early 19th century, grew more pronounced during 1850s and finally transformed into a war on 12th April 1861 with the attack on Fort Sumter, near Charleston in South Carolina.

The history of United States of America started with the 'Declaration of Independence', a statement adopted by Continental Congress on 4th July 1776, which announced that 13 American colonies, at war since 1775 with Great Britain, were independent states and thus no longer a part of the British Empire. The war of Independence (also called American Revolution) ended with American victory in October 1781, followed by the 'Treaty of Paris' in 1783, the formal British abandonment of any claims to the United States.

The constitution of United States was written in 1787 and ratified in 1789. For more than a century before the constitution was drafted, black African slavery had existed

in the North American English colonies. Whether slavery was to be permitted under the new constitution was a matter of conflict between the North and South. The constitution of the Union, however, ensured slavery throughout the USA. But by 1804 most Northern states, had effectively abolished slavery, while in the Southern states slavery grew and became an inextricable part of the economy and way of life.

Between 1776 and 1819 the country had grown from 13 states to 22 states, with 11 free-states and 11 slave-states. In an effort to maintain balance of power between free-states and slave-states in Congress, the United States Congress passed an agreement, known as "Missouri Compromise" in 1820. The agreement accepted Missouri as a slave-state and Maine as a free-state. The Congress, once again to avert a crisis between the North and South on the issue of slavery, passed a package of five laws known as "Compromise of 1850". It defused the sectional conflict, although each side disliked specific provisions made under the agreement.

In 1854, the territories of Kansas and Nebraska wanted to become new states of the USA. But the issue left to be resolved was whether they would have slavery or not. The Kansas Nebraska Act passed by Congress in 1854, which allowed people in the territories to decide of themselves whether or not to allow slavery within their boundaries. As a result violence erupted in the region and continued for a few years. Kansas was admitted to the Union as a free-state in 1861 and Nebraska also became a new free-state but in 1867.

On 16th June 1858, Abraham Lincoln was nominated by the Republicans as their candidate from the state of Illinois for the US Senate. Lincoln in his address cautioned the audience to the danger of division of the country between slave and free-states by saying "Every Kingdom divided against itself is brought to desolation; and every city or house divided itself shall not stand." On 6th November 1860 Lincoln was elected President of USA as a Republican candidate. He won the election entirely on the strength of his support from the Northern states.

The Southern states got tired of all the fighting and arguing on the issue of slavery and as a result decided to break away from the USA. Between December 1860 and February 1861, seven deep-south states seceded, starting with South Carolina, Mississippi, Florida, Alabama, Georgia, Louisiana and Texas. On 4th February 1861 these states formed "Confederate States of America" with Jefferson Davis as President. Within next two months four more Southern slave-states – Virginia, Arkansas, North Carolina and Tennessee – also joined the confederacy.

On 4th March 1861, Abraham Lincoln was inaugurated as the 16th President of the United States of America. On 12th April 1861, Confederate forces attacked a US Military installation at Fort Sumter, in South Carolina and that started the American Civil War – a bloody conflict between the Union and the Confederates.

The Federal Government of USA, called the Union, led by President Abraham Lincoln fought against the Confederates in thirteen battles during 1861-1865. The Union was supported by twenty Northern free-states (namely, California, Connecticut, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Nevada, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Vermont, and Wisconsin) and five border states (namely, Delaware, Kentucky, Maryland, Missouri and West Virginia).

5.1 Weapons

Although the American Civil War started with old-fashioned infantry charges and cavalry attacks, many new technologically advanced weapons were brought into use by both the Union and the Confederates during the course of the war. Major weapon developments included the invention of the percussion cap; of the rifled gun and cannon barrels; of cylindro-conical bullet; of pistols and revolvers; of rapid firing guns; etc.

The percussion cap ignition system was invented by Scottish Clergyman Alexander John Forsyth (1768-1843) in 1805 and introduced later in warfare in 1850. It was a crucial invention as it enabled muzzle-loading guns to fire reliably in any climatic condition of the battle field.

Rifling of the musket barrel was another great improvement which increased range and accuracy of gun fire. Rifled breech-loading guns were also extensively used in the wars. Claude-Étienne Minié (1804-1879), a French Army officer, invented the Minié Ball in 1847 and the Minié rifle in 1849, which came into prominence in Crimean and Civil war. The rifle was designed to allow rapid muzzle-loading (loading of the gun from the forward open end of the gun's barrel) of rifles and therefore had widespread use as a mass battlefield weapon. The Minié ball is a spin-stabilised, muzzle-loading rifle bullet used in the Minié rifle. Several models of rifled cannons were used in the Civil War. Samuel Colt (1814-1862), an American inventor, had developed a practical 'revolving gun' or revolver and patented it in USA in 1836. Colt's revolver was a practical adoption of 'revolving flintlock'. The Colt Army Model of 1860, a six-shot revolver of .44 caliber was favourite of the Union, while the confederates preferred Colt Navy Model of 1861, a .36 caliber revolver.

Richard Jordan Galting (1818-1903) an American inventor, developed a rapid-fire weapon called 'Galting gun' in 1861. These guns were very large and heavy and

hence mounted on wheels. Galting guns were used mostly by the Union forces in the war. It was a forerunner of the modern machine gun.

5.2 Ironclad battleships

'The Napoleon', commissioned by France in 1850, was the first steam-powered battleship in the world. The first ironclad battleship 'La Glorié' was launched by the French Navy in 1859. The British Royal Navy developed its first ironclad battleship 'Warrior' in 1861. Ironclad ships were first utilised in the Crimean War and it transpired that they were formidable adversaries for traditional wooden warships of that time.

With the beginning of civil war in America both the belligerent sides developed steam-powered ironclad warships - 'CSS Virginia' by Confederate States Navy, and 'USS Monitor' by United States Navy. These two ironclad warships, supported by a fleet of wooden ships, fought a fierce battle near Virginia on 8-9 March 1861. A few wooden warships of both the sides were destroyed, but the ironclad warships survived opponents attacks and the result of the battle remained indecisive. While 'Virginia' was scuttled by the Confederates in May 1862, the 'Monitor' was lost at sea in December 1862.

5.3 Submarine boats

During the American Civil War the confederates built small, steam-powered submarines called 'Davids', one of which attacked battleship 'USS New Ironsides', off the coast of Charleston on 5th October 1863, but could not sink it. On 16th February 1864, another Confederate submarine 'Hunley' successfully sank 'USS Houstonic' off the Charleston coast. But the submarine too sank after completing its mission. The Union Navy also possessed a submarine warship 'Alligator' built in 1862 by French inventor Brutus de Villeroi (1794-1874). The 'Alligator' made two attempts to destroy enemy targets but never succeeded. It was lost off the North Carolina coast during a storm in 1863.

David Bushnell is also credited for building the first water mine in the world. Like his submarine, his mines when used against the British fleet during American Revolutionary war in 1778 were proved ineffective. During the American Civil War the confederates used water mines extensively against the Union. The confederates sank 27 vessels by mines. ■ high success rate, compared to sinking 7 Federal vessels by gunfire.

5.4 Railways

At the beginning of the Civil War in 1961, the Northern territory of USA had about 22,000 miles (about 35,400 km) of railroad and the Southern territory had about 9,000 miles (about 14,500 km) of railway track. The railways as a new mode of transportation were extensively used by both the belligerent sides. The railways moved large number of troops and hauled heavy ammunition, ration and medicine for the army at the battle field much faster than ever before.

5.5 The telegraph

The British made limited military use of telegraph for the first time at Varna during the Crimean War in 1854. By 1860, telegraph lines were laid in most of the eastern states of America. When Lincoln arrived for the inaugural in 1861, there were no lines connecting the War Department or the White House. He realised the great importance of electrical communication for the military and in May 1861 established the US Military Telegraph Corps. Telegraph operators were engaged in large numbers to assist the Union Army with technical expertise to transmit and receive messages. By 1862, more than 4,000 miles (about 6,500 km) of telegraph lines were laid for the benefit of Union Army. Throughout the period of Civil War, Lincoln extensively used telegraph in an unprecedented manner to communicate with his commanders stationed in the battlefields.

5.6 Balloons

Balloons were the first mechanism in air warfare for gathering useful military information from a height over the battlefields. The first successfully flown hot air balloons were built in France around 1783 by Joseph-Michel Montgolfier (1740-1810) and his brother Jacques-Etienne Montgolfier (1745-1799). During American Civil War, both Union and Confederate armies used balloons for reconnaissance.

Thaddeus Lowe (1832-1913), a professor of chemistry and an early balloon enthusiast, was appointed as the Chief Aeronaut of the Union Army Balloon Corps in 1861. On September 1861, his balloon the 'Union' ascended to about 1,000 feet (about 300 metres) near Arlington, across the Potomac River from Washington, D.C. From his balloon he telegraphed information on location of Confederate troops. The Union army in turn fired at the Confederate army accurately, without seeing them – the distance between the two troops was about three miles (about 5 km). The Union subsequently built a fleet of six more balloons. John LaMountain (1830-1878), another aeronaut also worked for the Union aerial reconnaissance at the same time. Due to several conflicting issues the Union balloon corps was dissolved in August 1863. The confederates also operated balloons for military reconnaissance, but with very limited success. They stopped using balloons after August 1863.

5.7 *Photography*

A comprehensive photographic documentation of the battle scenes was done for the first time during American Civil War (1861-1864). The wars caught on camera before the American Civil Wars, were the Mexican-American War (1846–1848) and the Crimean War (1854-1856), but not so extensively.

In 1839, Louis-Jacques-Mandé Daguerre (1787-1851) in France, in collaboration with Joseph Nicephore Niepce (1765-1833), invented photography by producing image of an object on a metal plate. The same year, William Henry Fox Talbot (1800-1877), an Englishman developed a photographic process that produced paper negatives and prints. During the next 20 years, much before the civil war, photography was developed to a great extent in Europe and America.

During the course of the American Civil War, more than 3,000 photographs were taken by the northern photographers - Mathew Brady (1823-1896), Alexander Gardner (1821-1882), George Barnard (1819-1902), Timothy O'Sullivan (1840-1882), and James F. Gibson (1828-1905), and the southern photographer - George S. Cook (1819-1902). Photography of activities in the battlefield was an extremely difficult and time consuming process then. The photographers had to follow the armies in different location to take photographs of battle scenes. They carried bulky cameras, heavy equipment, hazardous chemicals and even the darkroom in the battlefield on wagons.

In 1866, George N. Barnard released wartime photographs in *Photographic Views of Sherman's Campaign* and Alexander Gardner published his photographic work in *Gardner's Photographic Sketchbook of the American Civil War*. But both the works initially had very limited success. Mathew Brady, despite his significant photo-documentation of the Civil War, had also very hard time. After several requests, his negatives of wartime photographs were bought by US Congress in 1875. These invaluable comprehensive photographic records of American Civil War had been archived in the US.

6. *First World War*

The Great War of 1914-1918 or the First World War was centered on Europe, involving world's great powers, assembled in two belligerent allies the Allies and the Central Powers. It claimed lives of about 9 million soldiers and 13 million civilians. It is said to be the second deadliest war in Western history.

The Great Powers of the world in 1914 were the German Empire, Austria-Hungarian Empire, Kingdom of Italy, British Empire, Russian Empire, French Third Republic, United States, Empire of Japan, and the Ottoman Empire. According to a military agreement made in 1882 between Germany, Austria-Hungary, and Italy, each nation promised mutual help in the event of attack on any two other nations. The alliance, known as Triple Alliance, lasted until the beginning of World War I in 1914. An alliance among Great Britain, France and Russia, named as Triple Entente, was formed in 1907. This alliance was supported during World War I by various agreements with Japan, the United States, Portugal and Brazil. They fought against the Central Power made up of the German Empire, Austria-Hungarian Empire, Ottoman Empire, and the Kingdom of Bulgaria.

Historians are of the opinion that the causes of World War I are complicated and intertwined. They, however, consider militarism, alliances, imperialism and nationalism, as major root causes for the war. Militarism is the trend of a country towards development of army and military forces for national defense and also for protection of colonial interests. At the beginning of the 20th century, arms race had begun in Europe. The armies of France and Germany were doubled in number between 1870 and 1914. Expansion of naval force also became competitive between Great Britain and Germany. Further, much before the actual conflict took place, the great powers had drawn complete plans for military mobilisation, which awaited a go ahead signal. Alliances and treaties between European powers gave them a sense of security. But it was inevitable that in the event of a conflict between two countries, many more would join either sides and give it a shape of a great war.

Rivalry between European imperialist powers was one of the important causes that culminated in World War I. They thought it was all right to go for war to grab more territory and power in turn. By 1900 the British Empire had extended over five continents covering a quarter of the world. As a part of the Empire, the British ruled over Canada, India, South Africa, Egypt, Australia and New Zealand. They made huge amounts of money from these countries and their military presence was established almost all over the world. France had control over large part of Africa compared to German territories in the same continent. Due to industrialisation, these European countries were also keen to acquire more and more territories to have continuous supply of raw materials from their colonies and to market finished products.

The nationalism or patriotism of various European countries also contributed to the beginning as well as continuance of World War I. Nationalism motivated them to compete for the largest army and navy, in order to prove

Propagation
A Journal of Science Communication

their dominance and power. Nationalist movements had resulted in unification of Italy in 1861 and that of Germany in 1871. Nationalism of the Slavic people in Bosnia and Herzegovina created problems for Austria-Hungary and the Balkans, as they desired to be a part of Serbia.

The spark that initiated the chain reaction, which resulted in the explosion of the Great War in Europe, was due to assassination of Franz Ferdinand (1889-1914), the heir of Austria-Hungarian throne, and his wife on 28th June 1914 during their visit to Sarajevo, a city of Bosnia in the south-east corner of the Austria-Hungarian Empire. The killer, Garvilo Princip (1894-1918), was a Serbian nationalist belonging to Bosnian Black Hand Gang. Austria-Hungary was convinced that Serbia had conspired against them for the murder. Immediately after the assassination Germany pleaded its full support to Austria–Hungary and motivated them to attack Serbia. On 28th July 1914, Austria-Hungary declared war on Serbia. Russia, in turn, when approached by Serbia for military help, ordered mobilisation against Austria-Hungary. On 31st July 1914, Germany asked Russia to stop mobilisation. Russia ignored German advice by saying that their mobilisation was only against Austria-Hungary and not against any other nation. At the same time France declared that in the event of Russo-German conflict, it would act in its own interest and started military mobilisation. On 1st August 1914, Germany declared war on Russia and after only two days, on 3rd August, it declared war on France. The Germans decided to attack France through neutral Belgium and invaded Belgium on 4th August. As a result, Britain declared war on Germany and Austria-Hungary. Japan, having a military agreement with Britain, declared war on Germany on 23rd August. Australia, Canada, India, New Zealand and the Union of South Africa, being colonies and dominions of Britain, offered military support to the Allied force. United States declared its policy to remain neutral. Italy too remained neutral. Thus World War I began.

6.1 Machine guns

Machine guns are fully automatic mounted or portable firearm that can fire rounds of ammunition in quick succession from a magazine or a belt. All the super powers of WW I including the US had developed machine guns at some stage before or during the WW I. Machine guns were extensively used by belligerent armies during the war.

Hiram Maxim (1840-1916), an American-born British inventor developed the first self-powered machine gun, known as Maxim gun in 1884. The gun was first used during the First Matabele War fought during 1893-1894 between British South African Company and Matabele people in Rhodesia. The Maxim gun was thereafter used in the Anglo-Aro War (1901-1902), a conflict between British Empire and Aro confederacy in southeastern Nigeria.

The British Vickers gun was an improvement on Maxim gun of 1884 and was adopted for military use in 1912. It was a water-cooled machine gun which weighed 20 kg and could fire 450 rounds per minute. Madsen machine gun was developed by W.O. Madsen in 1896 and was adopted by Denmark in 1903. It was used by Russian Army during Russo-Japanese War (1904-1905) and also by the German army in 1914.

The Hotchkiss machine gun was adopted by France in 1900 and various models of the gun were produced until , a gas powered, air-cooled model was introduced in 1914. A further improved version of the gun appeared in 1915; it weighed 23 kg and could fire 600 rounds per minute. The gun's effective range was about 3,800 metres. The chauchat, a French light machine gun, was developed in 1907 and modified in 1915. France produced 250,000 chauchats during WW I, and used it throughout the war. St. Etienne gun, a heavy machine gun, produce by France in 1907, was withdrawn from service in 1916, due to difficulties experienced in its operation.

During WW I, Germany widely deployed Bergmann MP18 gun, a sub-machine gun that used 9-mm ammunition rounds loaded via a 32-round magazine. Bergmann MG-15nA machine gun was adopted by Germany in 1915. It range was 400 m, and was often compared with British Lewis light machine gun. Maschinengewehr 08, German army's standard machine gun adopted in 1901, was similar to Maxim gun of 1884 in design. It used 7.92-mm ammunition, to fire at a rate of 250 rounds per minute to a range of 400 metres. An improved version of this machine gun was the Parabellum gun, which weighed only 10 kg and could fire 700 rounds per minute. It was introduced in service towards the end of 1914. A modified version of this machine gun, the Spandan gun was introduced in 1916. This 12-kg gun used 7.92-mm ammunition which could be fired at a rate of 500 rounds per minute.

Fiat-Revelli was the first mass produced machine gun of Italy. This 17-kg, 6.5-mm caliber, water-cooled gun was designed in 1908 and brought into use of Italian army in 1914. It could fire 400 rounds per minute up to a distance of 1,500 metres accurately. World's first genuine sub-machine gun Villar Perosa was introduced in the Italian army in 1915. The gun could fire 300 rounds per minute accurately to a distance of 800 metres.

The American Browning gun, similar to the Maxim gun and Vickers gun, was developed by John Moses Browning (1855-1920) in 1910 and adopted by the US army following America's entry into the WW I in 1917. In 1918 Browning developed an automatic rifle which was used by the American forces in the final year of the war. The gun was air cooled, gas operated, magazine fed and used 0.30 inch ammunition. Its firing rate was 550 rounds per minute at 600 yards (about 550 metres).

At the start of WW I, American Expeditionary Force (AEF) adopted the Colt-Browning machine gun. It was the first successful gas-operated machine gun designed by Browning. It was modified in 1917 to produce the Marlin gun, a 0.30-inch light machine gun. Marlin gun was air-cooled, gas operated, and could fire 650 rounds per minute.

Colonel Isaac Newton Lewis (1858-1931) of US Army designed the Lewis gun, an early light machine gun, in 1911. It was used widely by the British from 1915 onwards. This air cooled gun weighed 12 kg and could fire 500-600 rounds per minute up to 600 metres.

The only machine gun developed by Russia was the 'Pulemyot Maxima'. This water-cooled, 7.62-mm machine gun was developed in 1910 and was similar in design to the Maxim gun. It could fire 250-300 rounds up to 2,700 metres.

6.2 Flamethrowers

The first modern flamethrower, Flammenwerfer, was invented by German engineer Richard Friedler in 1901. These powerful weapons used pressurised air, carbon dioxide or nitrogen to push oil through a nozzle, which was ignited by a charge, producing a jet of flame. Flamethrowers were mainly used to clear enemy soldiers from the trenches. Richard Friedler developed two types of flamethrowers - the smaller version Kleinflammenwerfer, was a portable one carried by one person, and the larger version, Grossflammenwerfer, was suitable for transportation, also by a single person. From 1911 onwards the German army deployed flamethrowers in three specialised battalions. They used it first against French trenches at Malancourt, north of Verdun on 26th February 1915. The Germans made a surprise attack with the flamethrowers on the British troops at Hooge in Flanders on 30th July 1915. The French also used their portable one-man flamethrower, Schilt, a superior build to the German models, in trench attacks against the Germans during 1917-18. The Germans too produced an improved lightweight model of flamethrower, Wex, in 1917. The British army used 'Liven Large Gallery Flame Projectors', developed by a Royal Engineers officer William Howard Livens, in the Battle of Somme in 1916 and also in an offensive in 1917 near Diksmuide, Belgium.

6.3 Tanks

The advent of tanks to counter the ills of trench warfare brought in a new era of mechanised warfare and profoundly altered the land warfare tactics. The longstanding need for armoured self-propelled weapons, which would be able to move powerfully in any terrain, was met with the development of the tank. WW I also witnessed the first-ever tank-versus-tank battles. In 1915, 'Holt' tractors were introduced by British and French armies to haul artillery and other supplies to the battle-fields. The vehicle ran on continuous caterpillar tracks instead of wheels, and thus provided contact with a large surface of the ground. This innovation was adopted at the time of design of military tanks.

The 'Little Willie', constructed by Britain in 1915, was the first completed prototype tank in history. The 16.5-ton tank had a crew of six and could cross a trench of 5-foot (about 1.5-metre) width. The 'Schneider CA1' was the first French tank introduced in 1915, while 'St. Chamond', developed in 1916, was the second French tank. The French light tank 'Renault FT-17', introduced in 1917, was the most revolutionary in tank design history. It was in service from 1917 till 1945. This 6.5-ton light tank had two crew members and moved at a speed of 7 km/hour. The 'Holt' gas-electric tank, built during 1917-1918, was the first prototype tank of USA. This 25.4-ton tank carried six crew members and moved at a speed of 10 km/hour. 'Sturmpanzerwagen A7V' was the first German attempt at a tank in 1917. It, however, had limited success in WW1. The six-ton tank *M1917*, was USA's mass produced efficient tank, which was extensively used in WW1. Great Britain developed the maximum number of tanks between 1916 and 1918, known as Mark I to Mark X, which served varied military purposes.

6.4 Battleships

Battlecruisers. Developed in the first decade of the 20th century, they formed part of navies of Britain, Germany and Japan in WW I and were primarily used as fast and hard hitting battleships. Great Britain introduced several battlecruisers between 1908 and 1916, under the classes 'Invincible', 'Indefatigable', 'Lion', 'Queen Mary', 'Tiger' and 'Renown'. Germany also brought into service a few battlecruisers between 1911 and 1917, belonging to 'Von der Tann', 'Moltke', 'Seydlitz', 'Derfflinger', and 'Hindenburg' classes.

Dreadnoughts. The predominant battleships of the early 20th century were the dreadnoughts. The first of its kind, 'HMS Dreadnought' was built by the British Royal Navy in 1906. It had two revolutionary features: an all-big-gun armament and driven solely by steam turbines. By 1914 the British Navy had 19 dreadnoughts and 13 under construction, Germany had

13 battleship similar to dreadnoughts and seven under construction. Other countries which had introduced battleships of dreadnought class in 1914 were USA (8), France (8), Austria-Hungary (2), Italy (1), and Japan (4). Britain subsequently produced improved dreadnought ships, namely, 'Queen Elizabeth', 'Warspite', 'Barham', 'Valiant', and 'Malaya', all of which served during WW I.

Pre-dreadnoughts. Pre-dreadnought battleships built between 1889 and 1908 were possessed by Great Britain (48), and Germany (24). Other allied countries of Great Britain and Germany also had pre-dreadnought ships, which were used during WW I. Pre-dreadnoughts replaced the ironclad warships of 1870s and 1890s. 'USS Texas' launched in 1892 was the first pre-dreadnought battleship. Such battleships were built from steel, protected by hardened steel armour and carried a main battery of heavy guns supported by a secondary battery of lighter weapons. 'HMS Majesty', British battleship of this class was introduced in 1895.

6.5 Torpedo boats

Torpedo boats, small but fast vessels to carry torpedoes into battle, were introduced during the American Civil War. In Russo-Japanese War (1904-1905), the Imperial Russian Navy deployed many torpedo boats to launch torpedoes in three major battles. The Imperial Japanese Navy too launched torpedoes and deployed torpedo boat destroyers (TBD) which were invented in 1892 by British Royal Navy. During the WW I Britain and its allies deployed 420 torpedo boats and torpedo boat destroyers, while Germany and its allies used 178 torpedo boats and destroyers.

6.6 Submarines

In 1888, the Spanish Navy launched the first fully capable military submarine 'The Pear'l which could fire torpedoes under the sea and move at a speed of 10 knots. French Navy also launched a fully functional military submarine 'Gymonte' in the same year. Next development was Ireland's 'Holland VI' submarine of 1896 which made use of internal combustion power on the surface and electric battery power for submerged operations. In 1900 US Navy purchased this submarine and named it as 'USS Holland'. Germany completed its fully functional military submarine 'Forelle' in 1903. They sold this vessel to Russia in 1904, for use in Russo-Japanese war. German Imperial Navy's first U-boat design 'U1' was commissioned in 1906. In 1914, at the start of the war the super powers of Europe had significant number of submarines with their Navies: Great Britain (77), Russia (58), France (62), Germany (48), and Ottoman Empire (7). All of them lost a number of submarines during the WW I.

Table I. A comparison of combined fleets of operation between the Entente and Central Power during WW I

	Great Britain and Allies	Germany and Allies
Pre-dreadnoughts	54	45
Torpedo boats and Torpedo boat destroyers	420	178
Submarines	179	44

6.7 Aircrafts

In 1903, Wilbur Wright (1867-1912) and Orville Wright (1871-1948), the American engineer brothers, created the first powered airplane in the World. They had been running the 'Wright Cycle Company' in Dayton, Ohio since 1892, for manufacture of bicycles. Between 1900 and 1902 they built and flew three biplane gliders. Development of propeller and engine enabled them to build a powered airplane. On 17th December 1903, their 'Flying Machine', with Orville at the controls made a short flight of 12 seconds and covered a distance of 120 feet (about 36.5 metres) at Kitty Hawk in North Carolina. Wilbur too flew on the same day for 59 seconds at Kill Devil Hills near Kitty Hawk. Their airplane of 1905 could remain air-borne for over 35 minutes and in 1908 their airplane remained afloat for 2 hours and 20 minutes. In 1909, Wright brothers founded the 'Wright Company' to build and sell airplanes in the United States. They also licensed various manufacturers to produce airplanes of their design in Europe and also taught many officers to fly an airplane.

Louis Blériot (1872-1936), a French aviator and engineer built a monoplane, an aircraft with one set of wing surfaces, in 1905. In collaboration with Morane Saulnier (1881-1964), another French man, he designed an advanced monoplane 'Blériot XI' in 1908. Louis Blériot crossed the English Channel, from Calais to Dover, in 36.5 minutes by his 'Blériot XI' in 1909.

As the aircrafts gained stability in flights, many countries decided to use aircrafts for warfare. During Italio-Turkish War (1911-1912), Italy used airplanes for military reconnaissance and bombing. During first Balkan War (1912-1913), the Bulgarian Air Force bombed Adrianople in Turkey. The Greek Air Force dropped bombs over the Dardanelles, a narrow strait in northwest Turkey connecting the Aegean Sea to the Sea of Marmara, which incidentally was the first naval-air cooperation in history. Effective use of aircrafts in these two wars drew attention of armies worldwide and great importance was given for fast development of aircrafts for military operations. 1914 to 1918 was a period when very rapid technological development in design and development of military aircrafts occurred. From slow moving, unarmed, fragile aircrafts they evolved into

fast, agile, sturdy deadly fighters and bombers. Ninetyfive military aircrafts were produced during WW1 by Austria-Hungary, France, Germany, Great Britain, Italy, Russia and United States (Table II), of which 41 were reconnaissance aircrafts, 52 were fighters and 25 were used as bombers. Germany established its superiority over others by producing 37 different aircrafts and they used their planes only during WW1. Other six countries used aircrafts, as detailed in Table III, of their own designs, as well as of others during the war.

In 1914, Germany produced three reconnaissance aircrafts, namely, 'Albatros B.I', 'Aviatik B.I' and 'Hansa-Brandenburg B.I'. They designed and developed new aircraft in the following years (Table IV) under the series Albatros, Aviatik, Fokker, Gotha, AEG and Hansa-Brandenburg, to serve German Air Force as trainers, fighters, bombers and reconnaissance aircrafts.

British Air Force entered WW1 with their single-seater fighter aircraft 'Bristol Scout' in 1914. They introduced another fighter aircraft 'Vickers FB.5', a two-seater biplane, into operation in early 1915. Great Britain developed several fighters thereafter, namely, 'Arico DH.2', 'Bristol Scout D', 'RAF FE.2', 'Sopwith Pup', 'Bristol F.2b', 'Sopwith F1 Camel', 'Sopwith Triplane', and 'RAF SE.5a'. Worth mentioning bombers they developed were 'RAF FE2', 'Sopwith 1$^{1/2}$ Strutter', 'Avro 523 Pike', 'Airco DH.4', 'Airco DH.9', 'Avro 529', 'Vicker Vimy', 'Blackburn RT.1 Kangaroo', and 'Handley Page HP 0/400'.

'Farmann MF.11 Shorthorn' was an early-war French aircraft used for reconnaissance and bombing. In 1915 France produced three more bombers, namely,'Breguet br. M5', 'Caudron G.4' and 'Voisin Type 5'. 'The Brequet br.14', introduced in 1917, was the single most important aircraft in the whole course of the war. This biplane was a fighter, bomber and also served for reconnaissance. The 'Caudron R.11', which appeared in 1918 was a reconnaissance, bomber and escort aircraft of the French Air Force.

'Nieuport Nie.11', produced in 1915, was the first true Allied fighter of WW1. In a year this aircraft was improved in performance and named as 'Nieuport Nie.17. France introduced two more fighter aircrafts, *Harriot* HD.1' and 'SPAD S.VII' in 1916. The 'SPAD S.XII', a cannon-armed biplane fighter aircraft was introduced in the war in 1917.

Austria-Hungarian aircrafts ;Lohner B.VII' and 'Lohner C.I' developed in 1915 and 1916 respectively were reconnaissance planes. Three versions of 'Lloyd (C.II, C.III and C.IV)' produced in 1915 were also used for reconnaissance. The 'Hansa-Brandenburg C.I' and Hansa-Brandenburg D.I' were fighter aircrafts of 1916. The 'Aviatik D.I' and 'Phonix C.I', produced by Austria-Hungary in 1917, were also fighter planes. The last reconnaissance fighter aircraft which entered in service in 1918 was the 'Ufag C.I', a two-seater, 230-horsepower, biplane.

Developed in 1915, Italian 'Caproni Ca.1' was the first useful heavy bomber in the world. Italian bomber 'Caproni Ca.3' was launched in 1917. 'Ansaldo A1 Balilla' (Hunter) biplane was first Italian fighter aircraft.

First introduced in 1913, the Sikorsky Ilya Mourometsseries of aircrafts were the world's first four-engine bomber aircrafts in operation.

The 'Aeromarine 39', developed in 1916 by USA, was a versatile two-seater aircraft for land-based and seaplane training. The 'Aeromarine 40' of 1918 was a flying boat. 'Standard J-1' of 1917 was used by the US army as a trainer, while 'Vought VE-7 Bluebird' launched during the same year was fighter-cum-training aircraft. The 'Martin MB-1', the first American-designed two-engine heavy bomber came into operation in 1918.

Table II. Military aircrafts developed during WW1

Country of origin	1914	1915	1916	1917	1918	Total
Austria- Hungary		2	3	3	1	9
France	1	5	3	6	1	16
Germany	3	6	8	14	6	37
Great Britain	1	4	5	12	3	25
Italy		1		1	1	3
Russia		1				1
United States			1	2	2	5

Table III. Aircrafts used in combat during WW1

Name of the country using aircrafts	Country of origin of aircrafts							Total No. of aircrafts used during WW1
	Austria-Hungary	France	Germany	Great Britain	Italy	Russia	United States	
Austria-Hungary	8		6					14
France		16		3	1			20
Germany			37					37
Great Britain		10		25	1			36
Italy		9			3			12
Russia		11	1	2	1	1		16
United States		8		8	2		5	23

Propagation
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6.8 Chemical weapons

In August 1914, Germany invaded Belgium and subsequently attacked France. At that time the French made the first use of a chemical as a weapon by firing grenades of tear gas (xylyl bromide) on the German army. The effect, however, was insignificant. In October 1914, German troops fired shells filled with chemical irritants against the British positions at Neuve Chappelle in France. During the Second battle of Ypres, on 22nd April 1915, the German Army discharged 180 tons of chlorine gas on allied trenches. As a result the French and Algerian troops fled and allowed an opening of about 8 to 9 km in the Allied line. The Germans conducted a second chlorine gas attack at Ypres on 24th April on Canadian troops and the third attack on 2nd May on British troops. Chlorine is a toxic gas that irritates the human respiratory system. Chlorine gas inhaled at concentrations above 30 ppm reacts with water and cells in human body, and in turn changes into hydrochloric acid and hypochlorous acid. On 25th September 1915, the British army made its first chemical weapon attack on German troops with chlorine gas at the battle of Loos in France.

On 19th December 1915, Germany attacked British troops at Wieltije near Ypres with chlorine and phosgene gases. In March 1916, phosgene gas shells were fired on French troops in Verdun by the Germans.

Phosgene is a toxic gaseous compound of carbon, oxygen and chlorine, with the chemical formula $COCl_2$. It is produced by passing carbon monoxide and chlorine through activated coal or charcoal. Phosgene is an industrial reagent, used in synthesis of organic compounds including pharmaceuticals and production of dyes. Phosgene, when inhaled, reacts with water in the lungs and creates hydrochloric acid and carbon monoxide. It is deadlier than chlorine gas, but has a drawback that symptoms of attack on respiratory tract of the affected persons appear about twenty-four hours after inhaling.

The chemical warfare reached its peak with the use of mustard gas by Germany in July 1917 in Ypres region of Belgium. Mustard gas, chemically known as bis- (2-chloroethyl) sulphide, is a compound of carbon, hydrogen, chlorine and sulphur, with the chemical formula $C_4H_8Cl_2S$. It was not specifically a killing agent, but was used to disable the enemy and pollute the battle field. The gas was a lung irritant, skin blistering agent and remained active on the battlefield soils for many days. In 1916, German scientists, Wilhelm Lommel and Georg Wilhelm Steinkopf jointly developed a method for large-scale production of mustard gas.

During the period between 1915 and 1918 both Allied and Central Powers used tear gas, chlorine gas, phosgene gas and mustard gas as chemical weapons to attack their opponents.

7. Second World War

World War II was a global conflict involving most of the nations of the world and was fought during 1939-1945 between the Allies and the Axis powers. The Allies were primarily a group of three nations, namely United Kingdom, Soviet Union and the United States, who were also supported by France, China, Canada, Australia and others. The opposing Axis powers were formed by Germany, Japan and Italy, who were supported by Hungary, Romania, Bulgaria and other like-minded countries. The battles of WWII were fought in Europe, the Pacific, the Atlantic, South-East Asia, China, Middle-East, Mediterranean, Africa, and briefly in North America. It was a modern war, which mobilised available resources and the population of the belligerent nations and took place on land, in air, on sea surface and under the sea.

Germany faced severe economic crisis after World War I. Further, there was a negative impact on German economy due to Wall Street crash in the US, from whom funds used to flow to Germany. The Nazis offered radical solutions to overcome the setback in Germany and as a result they came to power in 1933 with Adolf Hitler as the Chancellor.

The first of a series of conflicts of WWII started when on 1st September 1939, Germany invaded Poland. Following the invasion, Britain and France declared war on Germany on 3rd September 1939. On 10th May 1940, Germany launched invasion of Western Europe by attacking the Netherlands, Belgium and France. Further, in a small-scale invasion, Italy attacked France on 10th June 1940. The Empire of Japan invaded French Indo-China during 22nd-24th September 1940. On 22nd June 1941, Germany invaded the Soviet Union. On 7th December 1941, in a surprise pre-emptive military action, the Empire of Japan attacked Pearl Harbor, in Hawaii, which is a territory of the United States. Japan also attacked British installations on the same day at Singapore and Hong Kong. On 8th December, Japan declared war on the United States and British Empire. The United States, in turn, declared war on Japan, the third Axis power. Germany and Italy, the other two Axis powers, declared war on United States on 8th December 1941. On the same day, the United States responded by declaring war on Germany and Italy. Thus by that time all the major Allies and Axis nations were involved in the war.

On 7th June 1942, the Japanese Navy lost a three-day battle to US Navy at Midway island in the Pacific Ocean. In the same year German forces in Africa were defeated by Anglo-American forces. On 2nd February 1943, German forces were defeated by the Soviet Union at Stalingrad On 10th July 1943, the Mediterranean island of Sicily, under Italy, was invaded by armed forces of the UK, US and Canada. On 25th July, the Italian dictator, Benito Mussolini stepped down from the post of Head of Italian Armed forces. On 3rd September 1943, the Allied troops invaded mainland Italy and after five days on, 8th September 1943, Italy signed an unconditional armistice with the Allies. On 25th August 1944, after four years under German occupation, Paris was liberated by the Allied forces and the Germans surrendered. On 7th February, the British Prime Minister Winston Churchill, US President Franklin D Roosevelt, and Premier of the Soviet Union, Joseph V. Stalin drew up plans for the final phase of war against Germany. On 14th February 1945, British and US bombers devastated the city of Dresden in Germany. On 12th April 1945, Franklin Roosevelt died and Harry S. Truman was sworn in as US President. On 21st April 1945 Russian army captured a few outlying suburbs of Berlin. Seven days later, Benito Mussolini, the dictator of Italy until 1943, was killed by Italian Partisans. Only three days later Germany announced that Adolf Hitler was dead. On 7th May 1945, General Gustav Jodi declared unconditional surrender by Germany and thus brought an end to six years of war in Europe. The US dropped atomic bombs on Hiroshima and Nagasaki in Japan on 6th and 9th August 1945. On 2nd September 1945, Japan surrendered unconditionally, which finally brought an end to World War II.

7.1 Radar

Radar (short for Radio Detection And Ranging) is a device for determining the distance and location of an object by measuring the time for the echo of a radio beam to return from it. During the first half of 1930s, prior to WWII, radio systems for detection and location of distant targets were developed independently in UK, Germany USA, USSR, France, Italy, Japan, and the Netherlands. Development of effective radars and their utilisation during WWII for detection of enemy ships and aircrafts greatly influenced the course of naval and air warfare.

James Clerk Maxwell (1831-1879), a Scottish mathematician and physicist, formulated four mathematical equations in 1864, the basis for modern electromagnetic theory, which state that (i) time-varying magnetic field produces an electric field, (ii) an electric current and/or time-varying electric field produces a magnetic field, (iii) an electric charge is a source for electric fields, and (iv) magnetic fields only exist in closed loops and no point source exists for them. In 1880s, Heinrich Rudolf Hertz (1857-1894), a German physicist, simplified and formalised Maxwell's equations into a more compact and symmetric form. Hertz experimentally proved that electricity can be transmitted by electromagnetic waves and such waves can be reflected and refracted. In 1904, Christian Hulsmeyer (1881-1957), a 22-year-old German inventor, demonstrated his 'Telemobiloscope', an anti-collision device for ships that worked like radar, in the harbour of Rotterdam, in presence of an international gathering of shipping experts. He claimed that the device could detect remote metallic ships in darkness, fog or rain and thus could avoid ship disasters. His invention, however, did not create much interest in Germany. Hans Eric Hollmann (1899-1960) was the next German pioneer who made significant contribution in development of radar between 1927 and 1935. He was a consultant of GEMA and Telefunken corporations -- leading German radar manufacturers of late 1930s. 'Freya', introduced in 1937, was the first land-based aircraft detection German radar, which operated at 120 to 130 MHz. 'Seetakt', developed in 1936, was a ship-board radar operating at 375 MHz. The next German radar introduced in 1941, was the 'Wurzburg', a high accuracy anti-aircraft gun targeting radar. It operated at 560 MHz at an operating range of up to 70 km. All these radars were used by the Germans during World War II.

In early 1930s the British realised the necessity of having an aircraft warning system. In 1935, Robert Watson-Watt (1892-1973), superintendent of British Air Ministry, demonstrated a 'Radio direction finding' system for detection and location of aircrafts at 100-km range. Based on Watson-Watt's work the British built a ring of coastal early-warning radar stations, known as Chain Home, before and during WW II. These radars operated at 20 to 30 MHz frequency with power of 350 to 750 kW at a range of up to 200 nautical miles (about 370 km). The British was, however, trying hard to develop radars in microwave range to have increased efficiency. University of Birmingham and Clarendon Laboratory of Oxford University were given responsibilities to develop microwave transmitters and microwave receivers respectively.

In 1930, US Navy and US Army initiated action for development of radio equipment that could locate presence of enemy ships and aircrafts. Earlier in 1922, while conducting communication experiments at Naval Radio Laboratory, Albert H. Taylor (1879-1961), an electrical engineer, and Leo C. Young (1891-1981) a radio engineer, noticed a ship interfering with their radio signal due to its presence in the path of the emitted signal. In 1930, Lawrence A. Hyland (1897-1989), an American electrical engineer working at US Naval Research Laboratory (NRL) detected reflection of radio waves from a passing aircraft. In 1934, Robert Morris Page (1903-1992), an American physicist, while working at NRL, successfully

designed a 60-MHz pulse-modulated transmitter which could track an aircraft up to one mile, flying up and down over Potomac River. In 1938, the NRL constructed the XAF, an experimental radar, which operated at 200 MHz at a power of 15 kW, and installed it on the battleship USS *New York*. It could detect aircrafts up to 100 nautical miles (nmi) and ships up to 15 nmi. In 1939, CXAM radar was produced by Radio Corporation of America (RCA) against a contract from NRL. The first CXAM radar was installed on the battleship 'USS California', which was later sunk during the Japanese attack on Pearl Harbor in December 1941. In an independent attempt William R. Blair (1874-1962), an American scientist and Army officer who led the US Signal Corp Laboratories (SCL) as its Director since 1930, made several attempts to detect presence of aircrafts by acoustical, infrared and finally by microwave means. In 1937, Paul E Watson (died in 1943), Chief Engineer of US Signal Crops Research Group (SCR) in Fort Monmouth, New Jersey, developed a prototype 'Searchlight Control Radar' SCR-268. Harold A. Zahl (1905-1983), an American physicist of US Signal Corps Laboratory developed two more radars -- SCR-270 for mobile use, and SCR-271 for fixed sites. They were operated at 106 MHz frequency with power output of 8 kW and were in service throughout WW II.

The radars developed by all the eight countries prior to WW II operated mostly in VHF range, i.e., 30 MHz to 300 MHz frequency band. Attempts were, therefore, made, particularly in England and Germany to increase the operating frequency or, in other words, to use shorter wavelengths, in order to get greater accuracy and better resolution. In 1940, John Randall (1905-1984) and Henry Boot (1917-1983) in Birmingham University invented the 'cavity magnetron', a high-powered vacuum tube that generated microwaves using the interaction of a stream of electrons with a magnetic field. With such cavity magnetron the British produced light-weight radar transmitters that could generate RF pulses at 3 GHz with an output power of 15 kW. This was a great achievement, as it contributed a 10-fold improvement in operating frequency over the German radar of that time.

In 1940, a seven-member team of British Technical and Scientific Mission, led by Henry Tizard (1885-1959), who was the Chairman of British Aeronautical Research Committee, visited USA and disclosed technical details of the cavity magnetron to their American counterpart. The Radiation Laboratory was set up at Massachusetts Institute of Technology in Cambridge, USA in October 1940 to develop microwave radar system, while British Admiralty carried out extensive research on microwave radar development in England at the same time. As a result of such collaborative effort, MIT in 1943 created the SCR-584 anti-aircraft microwave radar, one of the most efficient radars used during WW II. Both the British and the Americans used it extensively in the War. Another significant achievement of the British and the Americans was the Radio Proximity Fuse (RPF). It is a fuse that detonates a war head when the target is within some specified region near the fuse. RPF was installed at the front of a bomb. It was a massive breakthrough in technology which paved the way for miniaturisation of electronics, prior to solid state electronics. By 1945, 22 million radio proximity fuses were produced.

7.2 Anti-aircraft guns

As airplanes became effective weapons during WW I, the need for artillery to fire from ground and shipboard was felt by all the warring nations. During WW I, field artilleries up to 90-mm calibre were initially converted to serve as anti-aircraft weapons. This, however, was an inadequate arrangement. But great progress was made during the inter-war years, in development of range finders, gun laying mechanisms, rapid-firing time fuses, etc. As a result, many of the strong military powers of that time made remarkable progress in developing anti-aircraft guns prior to and during WW II.

In 1930, Bofors, a Swedish defence firm, designed the 'Bofors 40-mm gun', an anti-aircraft (AA) auto-cannon, which could fire 0.9 kg projectiles, 120 rounds per minute, up to a height of 3.2 km. This medium-weight gun was used extensively by most of the Western Allies and also by the Axis forces during World War II.

Throughout WW II, German forces used their '2-cm Flak 38 anti-aircraft cannon', which was first produced in 1934. Their next significant development was the '88 mm Flak 36 gun' of 1936, which was used as anti-aircraft and anti-tank artillery. During the WW II, Germans further developed 10.5-cm Flak 38, 12.8-cm Flak 40, 5.0-cm Flak 41 and 3.7-cm Flak 43 anti-aircraft guns. The 'Möbelwagen', produced in 1943, was the first German built self-propelled anti-aircraft gun. It was developed on the chassis of Germany's 1939 Panzer IV tank. Germany produced two improved versions of Möbelwagen, known as 'Wirbelwind' and 'Ostwind', in 1944. The 'Kugelblitz' developed in 1945, had a fully enclosed rotating turret, which previous self-propelled anti-aircraft German guns did not have.

Japan used its 'Type 10 120-mm anti-aircraft gun' as a coastal defense gun from 1921 to 1945. They also used 'Type 11 75-mm anti-aircraft gun' from 1922 to 1940, and 'Type 88 75-mm anti-aircraft gun, produced in large numbers, during 1927-1945. The Japanese Navy used the 'Type 96 25-mm AT/AA gun', a dual-purpose weapon, from 1936 to 1945. The most common Japanese anti-aircraft gun was the 'Type 98 20-mm AA

machine gun', more than 2,500 of which was produced and used throughout WWII. In 1942, Japan produced 'Type 2 20-mm AA machine gun', based on German Flak 38. They further produced the 'Type 4 75-mm AA gun' in 1944 for use in WW II.

During WW II, Britain primarily used its 'QF 3.7-inch anti-aircraft gun' which was an equivalent of German 88-mm Flak gun. The Royal Navy used its 'QF 2 pounder MK VIII naval gun' between 1930 and 1940. In 1938, the British Royal Navy introduced 'QF 4.5-inch MK I-V anti-aircraft naval gun', which was used throughout WW II.

In 1932, Italy designed the 'Breda model 35' 20-mm anti-aircraft gun and put it in service in 1935. In 1925, Norway developed the 7.5-cm L/45 M/16 anti-aircraft gun, which was in use during WW II. 'Orelikon 20-mm cannons' developed by Switzerland in 1927 was also used, on a limited scale, as an anti-aircraft gun during WW II.

In 1939, the Soviet Union developed a 37-mm automatic air defense gun M1939 (61K) and used it in WW II. The same year, they also produced a 88-mm air defense gun M1939 (52K). Soviet Union's light self-propelled anti-aircraft gun ZSU-37 was introduced in 1943.

American heavy machine gun Browning M2HB produced since 1921 was extensively used in WW II. This, however, did not fulfill the requirement of the US Navy. In 1940, America introduced 90-mm anti-aircraft-cum-anti-tank guns and put into service their super-heavy 120-mm M1 anti-aircraft gun during 1944-1945.

7.3 Aircraft carriers

First large-scale use of aircraft carriers was made by Japan, U.K. and the United States during WW II. In December 1941, when Japanese Imperial Navy attack the main naval base of the United States at Pearl Harbor, Japan had a fleet of carriers, consisting of 'Hosho', 'Akagi', 'Kaga', 'Ryujo', 'Soryu', 'Hiryu', 'Shokaku', and 'Zuikaku'. During the war they designed and launched four additional aircraft carriers. At the time of attack on Pearl Harbor, US had eight operational aircraft carriers - 'Langley', 'Enterprise', 'Lexington', 'Saragota', 'Yorktown', 'Hornet', 'Wasp', and 'Ranger'. At the beginning of WW II, British Royal Navy had 'HMS Ark Royal' aircraft carrier. The other aircraft carriers developed during the WW II by Royal Navy were 'Illustrious', 'Indomitable', 'Unicorn', 'Colossus', and 'Implacable'. 'KMS Graf Zeppelin' was the only aircraft carrier launched by Germany in 1938, but it was never over 80% complete. The French Navy had 'FR Bearn', the only aircraft carrier, which was commissioned in 1927. Italy started construction of 'Aquila', an aircraft carrier in 1941, but it was never completed.

7.4 Missiles

In 1942, Germany developed a 'Pilotless flying bomb', 'Vergeltungswaffe' 1, also known as V-1, which was first launched at London on 13th June 1944. During 1944-1945, Germany fired 9,521 V-1 bombs on Southern England, but anti-aircraft gun fire from Royal Air Force fighter planes destroyed 4,621 of them. V-1 was a cruise style guided missile that was propelled by a pulse-jet engine and carried a one-ton warhead. It was 25-ft (about 7.6 metres) long and had wing span of 20 ft (about 6 metres). They were launched from a fixed ramp and could travel at a speed of about 350 mph (about 560 km/h). Flying at an average altitude of 2,000 ft (about 610 metres) they could cover a distance of about 155 miles (about 250 km).

Robert Hutchings Goddard (1882-1945), an American physicist built the world's first liquid-fuelled rocket in 1926. Wernher von Braun (1912-1977), a German engineer studied Goddard's designs and developed three rockets of 'Aggregat' series between 1933 and 1935. Goddard and Walter Riedel (1902-1968), another German engineer designed much larger 'Aggregat-4' in 1937. This ballistic missile, commonly known as V-2, was the first of its kind in the world and has been considered by experts as the second most significant technical innovation of the WW II, next only to the atomic bomb. V-2 was first launched at Paris on 6th September 1944. During 1944-45 the Germans launched over 3,000 V-2s on their enemies. The V-2 travelled faster than sound and thus the enemies did not get any information before the impact.

7.5 Medicines

Significant advances were made in medicine during World War II, which saved the life of thousands of soldiers in the battlefields.

Blood plasma, the liquid component of blood, makes up about 55% of the total volume. It is the medium for blood cells to move through the body. It also performs many more useful functions of the body. Plasma was a vital element in treatment of the wounded soldiers in the battlefields. A project called 'Blood for Britain' was started in the United States with Charles Richard Drew (1904-1950), an African-American as its head in 1940 to collect blood in hospitals of New York and thereafter export it to Britain. Liquid plasma and whole blood were preserved and exported initially. Charles Drew and his team for the first time developed 'dried plasma', which was produced on a mass scale. Addition of distilled water to dried plasma could form liquid plasma in only three minutes. Such plasma was given extensively to the wounded allied soldiers in WW II.

In 1935, Gerhard Johannes Paul Domagk (1895-1964), a German biochemist discovered 'Sulfonamide', a new class of drugs for treatment of pneumonia, meningitis, gonorrhea, and other bacterial diseases. Use of sulfonamide powder on open wounds in human body prevented infection and thus greatly reduced mortality rate of soldiers during the war.

Alexander Fleming (1881-1955), a Scottish biologist and pharmacologist discovered the antibiotic penicillin in 1928. Penicillin is a life saving drug and has been very effective in treatment of syphilis, gangrene, and tuberculosis. Penicillin injections and tablets helped save countless lives during WW II.

Quinacrine, a synthetic anti-malarial drug was introduced in 1931 by the Germans. American chemists also succeeded in synthesising Quinacrine in 1941. The drug was sold under the name of Atabrine in the form of tablets.

In 1925, a Hungarian chemist, Janos Kabay (1896-1936) developed a method to extract morphine from opium poppy straw. Morphine injection was administered as a pain killer to patients during the war.

Othmar Zeidler (1859-1911), an Austrian chemist while conducting research at the University of Strasbourg in France synthesised a chemical called dichlorodiphenyltrichloroethane, or DDT, in 1874. In 1939, Paul Hermann Muller (1899-1965), a Swiss chemist discovered the insecticidal qualities of DDT. Field trials showed that DDT was effective against common house fly, louse, Colorado beetle and mosquito. Muller patented DDT in Switzerland (1940), Australia (1943), and United States (1943).

7.6 Atomic Bomb

German physicist Albert Einstein (1879-1955) propounded his Special Theory of Relativity in 1905 and as a part of this theory he made the intriguing point that large amount of energy could be released from a small amount of matter. This was expressed by the equation, $E = mc^2$, where E is the internal energy of the body, m is its mass, and c is the speed of light in a vacuum. When the atomic bomb developed later, it illustrated this principle.

In February 1932, through a series of experiments, British physicist James Chadwick (1891-1974) demonstrated the existence of the neutron, a previously unknown particle, in the atomic nucleus. Within nineteen months of discovery of neutron, in September 1933, the Astro-Hungarian physicist Leo Szilard conceived an idea of using a chain reaction of neutron collisions with atomic nuclei to release energy. In July 1934, Szilard filed a patent application in England for developing atomic bomb, describing basic concept of using neutron induced chain reaction to create explosions. He also gave the concept of critical mass – the smallest amount of material required for a sustained chain reaction. A few months earlier, in May 1934, Italian physicist Enrico Fermi irradiated uranium with neutrons and produced the first transuranic element, and also achieved unknowingly, the world's first nuclear fission.

In December 1938, German chemists Otto Hahn (1879-1968) and Fritz Strassman (1902-1980) detected the element barium after bombarding uranium with neutrons. The result was interpreted as being nuclear fission by Austrian physicists Lise Meitner (1878-1968) and Otto Robert Frisch (1904-1979). Frisch confirmed this experimentally on 13th January 1939.

On 25th January 1939, a team of physicists and chemists at Columbia University, New York, led by Enrico Fermi (1901-1954) experimentally verified the European discovery of nuclear fission of uranium via neutron bombardment. Other members of the team were Herbert L. Anderson (1914-1988), Eugene T. Booth (1912-2004), John R. Dunning (1907-1975), G. Norris Glasoe (1902-1987) and Francis G. Slack (1897-1985).

Next day, on 26th January 1939, Niels Bohr (1885-1962) made an announcement at the 5th Conference on Theoretical Physics at Washington, D.C. of the successful disintegration of uranium into barium with the release of high energy. The scientists present in the conference included Enrico Fermi (1901-1954), Harold C. Urey (1893-1981), Isidor I. Rabi (1898-1988), Otto Stern (1888-1969), John H. Van Vleck (1899-1980), Fritz London (1900-1954), Gregory Breit (1899-1981), George Eugene Uhlenbeck (1900-1988), and Leon Rosenfeld (1904-1974).

Three more physicists, Leo Szilard (1898-1964), Eugene Wigner (1902-1995), and Robert J. Oppenheimer (1904-1967), who were not associated directly with either of the two occasions, also heard about nuclear fission and realised that it might be possible to build a bomb. On 31st August 1939, Niels Bohr and John A. Wheeler (1911-2008) published a theoretical analysis of nuclear fission and predicted that uranium-235 is more fissile than uranium-238 and that the undiscovered element 94-239 (later known as plutonium-239) would be very fissile.

On 2nd August 1939, Albert Einstein wrote a letter to the US President Franklin D. Roosevelt (1882-1945), wherein he suggested that US should initiate research for development of atomic bomb in a big way, as it would have vast destructive power. It is believed that the letter was largely written by Leo Szilard in consultation

with fellow Hungarian physicists Edward Teller (1908-2003) and Eugene Wigner. The letter, however, was brought to the notice of President Roosevelt on 11th October 1939.

Meanwhile, on 1st September 1939, Poland was invaded by Germany, the Soviet Union and a small Slovak contingent. Although the battle ended on 6th October 1939 with decisive German and Soviet victory, as they divided and annexed the whole of Poland, it was the beginning of a series of conflicts that happened during World War II, between 1939 and 1945.

In March 1940, Otto Frisch (1904-1979), an Austrian-born British physicist and Rudolf E. Peierls (1907-1995), a German-born British physicist, while working in University of Birmingham, England, prepared a memorandum containing calculations about the amount of uranium required for creating an atom bomb. The memorandum reached Henry Tizard (1885-1959) an English chemist and Chairman of the Committee on the Scientific Survey of Air Defence, who in turn referred it to Military Application of Uranium Detonation (MAUD) committee formed by him on 10th April 1940. The MAUD committee consisted of George Paget Thomson (1892-1975), Marcus Oliphant (1901-2000), Patrick Blackett (1897-1974), Philip Moon (1907-1994), John Cockcroft (1897-1967), and James Chadwick (1891-1974). The committee considered that the scheme for a uranium bomb was practicable and likely to lead to a decisive result in the war. It recommended that the work should be continued on the highest priority in order to obtain the nuclear weapon in the shortest possible time. It further opined that collaboration with the United States, especially in the region of relevant experimental work, should be continued and extended.

In the US, Vannevar Bush (1890-1974), an American engineer and science administrator of National Defense Research Committee, was given the responsibility to coordinate the research activities on nuclear fission. Francis Simon (1893-1956) a German-born British physicist devised a method in December 1940 to separate uranium-235 from natural uranium containing approximately 99.3% U-238 and 0.7% U-235. James Chadwick at that time realised that a nuclear bomb was not only possible, but also inevitable. In the same year American scientists, Glenn T. Seaborg (1912-1999) and Edwin McMillan (1907-1991) synthesised plutonium at the University of California at Berkeley. It was predicted later that plutonium-239 isotope would be the most useful for nuclear fission.

On 10th May 1940, Germany launched the invasion of Western Europe by attacking the Netherlands, Belgium and France. The battle of Netherlands lasted only from 10th to 14th May and Germany occupied the whole country on 17th May. Belgium surrendered unconditionally to Germany on 28th May 1940. The battle of France took place from 10th May to 25th June 1940 between the Allies and the Axis powers and the result was the decisive victory of the Axis.

On 7th December 1941, Japan, the third Axis power, attacked the US naval base at Pearl Harbor at Hawaii, which was totally unprepared for a battle. US President Franklin Roosevelt addressed the Congress on the next day to ask for a consent to declare war on Japan. The proposal was approved and US declared war on Japan on 8th December 1941. Three days later, Italian National Fascist Party Chief, Benito Mussolini (1883-1945) declared war on US. Adolf Hitler on the same day declared war on US stating that Germany was obliged to join with Italy to defend its ally Japan, under the Tripartite Agreement signed between these counties in September 1940. As a result, resolutions of war against Germany and Italy was passed in the US senate immediately and a new law was passed which allowed US servicemen to fight anywhere in the world.

The Manhattan Project, a secret military project to produce nuclear weapon was initiated in June 1942. It was originally based in Manhattan, New York, as a small research program. The project eventually employed more than 130,000 people at more than 30 research and production sites across the United States, the United Kingdom and Canada with a budget of nearly two million US dollars. Three major research and production sites in the US were at the Oak Ridge Laboratories in Tennessee for production of enriched U-235; at Hanford, in eastern Washington state for production of weapons-grade plutonium; and at Los Alamos Laboratory, New Mexico for research, design and assembling of nuclear weapons. From 1942 to 1946, the project was under the command of Brigadier-General Leslie R. Grooves Jr. (1896-1970) of US Army Corps of Engineers. Immediately after his appointment in September 1942 Groves appointed Robert J. Oppenheimer (1904-1967) an American physicist, as the Scientific Director of the Manhattan Project.

On 2nd December 1942, Enrico Fermi and his team at the University of Chicago produced world's first controlled and self-sustained fission reaction. By 1943, three different designs of nuclear bombs had evolved under the Manhattan Project – all of which involved nuclear fission as the basic mechanism. The proposed designs were for (i) a uranium-235 gun-type bomb, (ii) a plutonium-239 gun-type bomb, and (iii) a plutonium implosion-type bomb. The first atomic bomb of the world, an implosion-type plutonium device, code-named 'The Gadget' was detonated by the United States Army on 16th July 1945 at a desert in New Mexico. The exploded bomb produced energy equivalent to the explosion of about 20 kilotons of TNT. Only two atomic bombs have ever been used in war – both detonated by United States over Japan near the end of

World War II. 'Little Boy', a uranium-235 gun-type bomb was dropped on Hiroshima on 6th August 1945 by Boeing Super-fortress 'Enola Gay' aircraft of the US Army Air Force. 'Thin Man', a plutonium-239 gun-type weapon, was planned, but never produced due to technical inconvenience. 'Fat Man', a plutonium implosion-type bomb, similar to 'The Gadget' in design was detonated on Nagasaki on 9th August 1945.

8. Conclusion

Wars have always been an integral part of human civilisation. In the Age of Tools, the era staring around 2000 BC and ending around 1500 AD, advancement of military technology was rather slow. However, with the advent of the modern age, which is believed to have commenced after the French Revolution, the nature of warfare started changing with ever accelerating rapidity. Inventions, innovations and discoveries - product of human creativity and endeavour - when exploited for development of the ultimate weapons, revolutionised warfare during the period from 1500 AD to the present time. The cases of the American civil war, the First World War and the Second World War have been selected to highlight the interrelation of science, technology and war, during the period between 1861 and 1945.

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Engineering Education in India: Past, present and future

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Abstract

The article is about how engineering education evolved in India along different models, the present scenario and the future roadmap. A comparative analysis has been done on an international basis regarding growth of technical education, curriculum, and accreditation and assessment procedures also – so that our global position is improved in technical education, thereby ensuring the growth of our economy.

There are strengths as well as weaknesses of the Indian technical education system. At present, India is producing a technical manpower of about 5-6 lakh. However, even with a 9% GDP, India ranks very low in HDI or knowledge economy index. Innovation is not a strong point of India's technical education system. That needs rectification.

The identification of weak points being imperative and immediate, the article attempts to make some conclusive remarks so that the technical education scenario in India can be improved and India can take a globally relevant seat in the engineering educational institute rankings.

***Keywords:** engineering education, India, growth, future roadmap, curriculum.*

1.0 Growth of Technical Education in India : different models

The study of the origin and growth of technical education in India shows that it took different routes: the colonial model, the nationalistic model, the research model, the university model, the IIT model, etc. Initially it was the colonial model, in which colonial rulers wanted to train the countrymen as subservient workers only. Five engineering colleges, namely, Guindy College of Engineering (1858) in Madras (now Chennai), Thomason Civil Engineering College (1847) at Roorkee, Poona Engineering College (1856) at Poona (now Pune), Calcutta Civil Engineering College (1856) in Calcutta (now Kolkata), and Victoria Jubilee Technical Institution (1887) in Bombay (now Mumbai) were established to produce 'technical hands' for the empire. The curriculum and the training in these colleges were geared mostly to meet the requirements of only subordinate grades of engineering services of the then British colony, India.

In the early twentieth century, nationalistic models developed. One attempt was the setting up of the National Council of Education, Bengal in 1906 by the nationalists, which later became Jadavpur University. The second one was Banaras Hindu University in 1916 by Madan Mohan Malaviya, where courses in technical education, law and medicine were imparted together with the inculcation of the spirit of Hindu religion 'for moral growth'. The growth of this model, carried on by dedicated *swadeshis* was done without any government help in the initial stages. However, the quality of education got recognised all over world.

Apart from the *swadeshis*, there were some individuals and industrialists through whose efforts and financial help technical education did make immense headway in India. The first research institution, the Indian Association for the Cultivation of Science, was started in Kolkata in 1876 by Dr. Mahendralal Sarkar. Another was the establishment of the Indian Institute of Science in Bangalore in 1909 by the industrialist J.N. Tata as a research institute where post-graduate and research courses were offered.

The universities were primarily imparting arts and science education in India from 1857 and were affiliating bodies. There was no roadmap for growth of technical education in the universities. It was only in 1951 that the first Indian Institute of Technology (IIT) was established with foreign collaboration, exclusively for undergraduate and post-graduate level technical education, based on the Sarkar Commission Report (1946).

2.0 University and Technical Education system

The university system in India started in India in 1857, and 150 years later we have only about 400 of them. After Independence, there has been a phenomenal increase in the number of universities, but the quantity and quality is still inadequate.

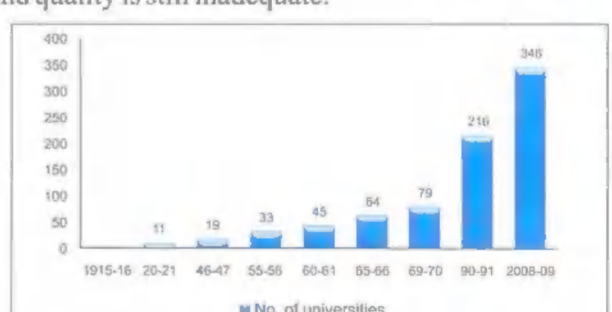

Fig. 1: Growth of the universities in India

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The number of universities has increased from 25 in 1950 to 346 in 2008; number of engineering degree level institutions has increased from 44 to 1,668; and the number of colleges has increased from 700 to 18,064, with the enrolment from 0.1 million to 11.2 million. But the Gross Enrolment Ratio (GER) is quite low relative to the other developed and developing countries. The GER in the USA, UK, Japan and Australia are 83%, 60%, 55% and 72% respectively. The Government has set a target to increase GER to 15% by the end of 11th plan and 22% by the end of 12th plan.

A major problem hindering the excellence of the Indian universities in the past was their affiliating nature. Earlier ones were modelled mostly on the British universities and majority of them were affiliating and examining universities, not teaching universities, let alone for conducting research. Postgraduate work was confined to the colleges, which were not properly equipped for such work and so the quality of postgraduate work was not of a very high order. The university curricula were inadequate to meet the needs of a scientific and industrial age. Thus the universities in the early stage, failed to contribute much to the advancement of knowledge in India, which was surely one of their obligatory functions. When Bombay University was established, it had no faculty of science and the only course in engineering was in civil engineering. Kolkata grew with a strong science base. However, the progress of technical education was hampered due to the lack of government support and funds as also an alienation of the university model from European and American ones in particular, which were research and industry oriented and professor centric rather than bureaucracy centric.

Though the universities offered a programme of undergraduate studies in pure and applied sciences, enrolment in these courses throughout the nineteenth century was very low, because, opportunities for Indians to advance in the scientific services were limited by colonial rulers. Most students preferred arts courses or professional courses like law and medicine. This was one main reason that hampered the growth of higher scientific and technical education within the domain of the university system.

Based on Prof. A.V. Hill's report in 1944, *Scientific Research in India* many research laboratories were created. A large pool of scientists from the universities was absorbed into the research laboratories, delinking research and teaching. Delinking of teaching and research has been one of the reasons for lack of availability of good faculties (P.Balaram, *Curr. Science*, **97**, 2009). Without the capability of knowledge generation, knowledge dissemination becomes difficult for a faculty. However, the indigenous growth models in space, atomic and defence research has been build up with inputs from our Institutions and have put India at par with global superpowers.

Some of these universities became the cradles of technical education in India, but not technical institutions, up to 1960s, till the Kothari Commission report came out. The universities of Calcutta, Bombay, and Madras, Banaras Hindu University, Aligarh Muslim University, Roorkee University, Anna University, Jadavpur University, and Bengal Engineering and Science University were some of them. Recently there has been a spurt in the growth of private, deemed and affiliating universities – whose qualities are questioned by the authorities themselves. Research universities need to be developed in India. A study is given below:

Table 1: Strengths and weaknesses of the university Research & Development system

Strengths	Weaknesses
* Continuous availability of students. * The academic ambience and peer groups in good universities facilitate objective inquiry. * Peer pressure and promotional requirements provide motivation for the faculty to be productive. * Availability of large body of peers with a wide spectrum of specialisations has the potential to promote interdisciplinary research. * Necessity to undertake sponsored research and consultancy promotes R&D on live problems pursued by national R&D agencies and industry. * The friendly rapport with international peers promotes international collaboration, which is difficult outside the university system.	* The manpower opting for research in recent times is essentially composed of those who could not find jobs. * It is relatively difficult to keep computing and experimental infrastructure up-to-date, at least in State universities. * More of incremental type of research than innovative. * Interpersonal relationship, credit sharing, etc., create problems for team work. * Outputs are more theoretical, not practical. * Research works get hampered because of the load of teaching.

[Source :Natarajan R., *The Indian Journal of Technical Education*, 2006]

An international comparison of engineering PhD outputs is shown in the following figure.

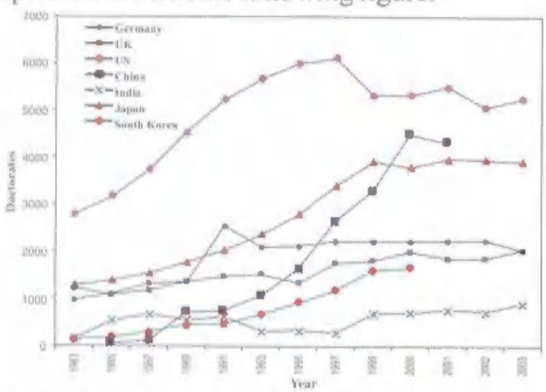

Fig 2: Engineering doctorates of different countries

[*Source*: Banerjee R, Mulley V (2010)]

The percentage of engineering PhDs as compared to Bachelors of Engineering degrees granted annually is given in Table 2. The percentage in India in 2002 was 0.66%, while Germany, UK, and USA maintained rates of 7-9%. China has increased engineering PhD output significantly in the last few years.

Table 2: Percentage of Engineering PhDs compared to Bachelors of Engineering degrees.

Country	1983	1985	1987	1989	1991	1993	1995	1997	1999	2000	2001	2002
Germany	4.41	4.70	5.39	5.23	8.66	7.66	7.70	8.05	8.87	8.92	8.97	6.81
United Kingdom	0.11	11.11	12.84	13.75	14.89	7.66	6.02	7.65	8.22	9.78	9.08	9.17
United States	0.04	4.08	4.99	6.79	8.38	9.09	9.48	9.81	–	8.94	9.28	8.36
China	–	0.09	0.15	0.65	0.67	0.88	1.11	1.51	1.67	2.11	1.98	–
Japan	0.02	1.93	2.01	2.30	2.32	2.67	2.87	3.31	3.80	3.68	3.79	3.81
South Korea	–	0.84	0.98	1.47	1.52	1.99	2.65	2.80	3.11	2.93	–	2.92
India	–	2.21	2.13	2.03	–	–	0.58	0.40	0.93	0.87	0.83	0.66

[Source : Banerjee R, Mulley V (2010)]

3.0 Indian Institute of Technology (IIT) and National Institute of Technology (NIT)

3.1 Indian Institute of Technology (IIT)

It was only after Independence that engineering and technological education got a great boost. Till the establishment of the Sarkar Commission in 1946 (the report was published in 1949) there was no specific thrust towards technical education in India. On the initiative of Sri Ardeshir Dalal, a visionary director of Tata Iron and Steel Company, the Government of India appointed the Sarkar Commission. The commission recommended the establishment of four institutes of higher education on the model of Manchester University (UK) and Massachusetts Institute of Technology (USA) to train scientists and engineers to support the economic and social development of India after Independence.

Though the first IIT at Kharagpur was established in 1951 with J.C. Ghosh as director, the IIT Act came into force in 1956. The other three IITs came into existence in a short span of a decade in Bombay (1958), Madras (1959), and Kanpur (1959). The College of Engineering, Delhi was converted into IIT in 1961. The five IITs had the benefit of assistance and partnership of foreign countries. Each IIT thus developed some of the culture of the assisting country – for instance, IIT Madras put heavy emphasis on workshop practice due to its tie up with Germany and IIT Bombay possessed heavy equipment. Though the traditions and conventions adopted by each of them are different, the spirit and approach to technological education is the same among the all IITs.

IIT Guwahati in northeastern India was started in 1994 and Thomason College of Civil Engineering became IIT Roorkee in 2001. In the 11th Five Year Plan, eight new IITs were sanctioned and IT-BHU has been converted in to IIT. The Indian Institutes of Technology Act has declared all the IITs "Institutions of National Importance".

During the last few decades, the IITs have contributed a lot to the upgradation and modernisation of science and engineering education in the country by bringing the concept of innovative, liberal and flexible academic systems. Considerable investment and effort has gone in to increase research activities, developing some centres of advanced research to give technological